

Triplet loudspeaker system

45 Book (d/R)

Function generator

Multi-point IR control

VOX AC30 revisited

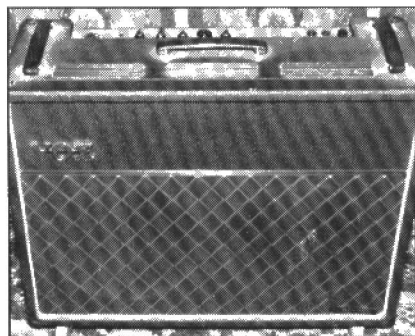
Dynamic range processor

DLF frequency reference

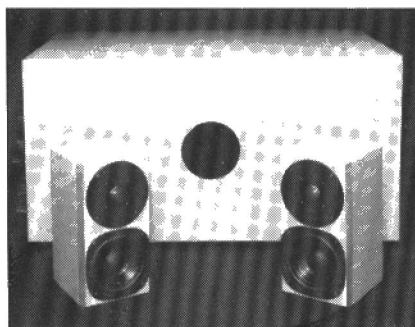
Class D amplifier

**Elektor  
Electronics**

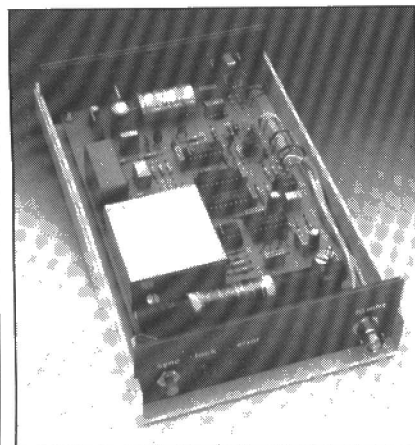




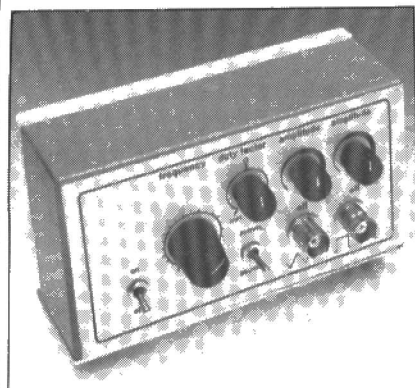
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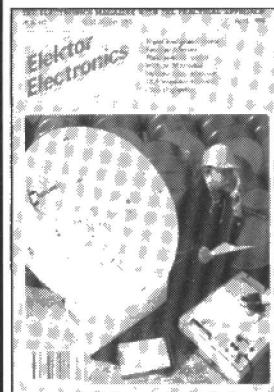
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- LinCMOS
- RS232 monitor
- DTMF decoder
- Sine wave converter
- Printer interface

\* We regret that owing to unforeseen circumstances this article could not be included in this issue.



## Front cover

People working in isolated areas of the world may be cut off completely from normal means of communication. This portable system, which allows engineers on exploration work, rescue teams, businessmen, reporters, and others whose job takes them 'out in the field' to make clear contact by telephone, or to transmit and receive data, has been developed by Marconi Marine.

Called 'Satpax', the system links — via the satellites of the International Maritime Satellite Organization — to the international telephone and telex network. Marconi claims that it can be used almost anywhere in the world.



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# OPTICAL COMPUTING

The news that Mitsubishi has succeeded in making the world's first optical chip must fill most of us with excitement (and a little regret that this first did not happen in Britain, although we have been in the forefront of research and development in optical computing from the start — but that's scientific life).

Light, or rather photons, is, of course, already being used on a rapidly expanding scale in telecommunications (fibre optics) and in optical memories (compact disc), but not yet in computing. This is not for want of trying, for research into optical computing has been going on for some years in several parts of the world, notably in Japan, the United Kingdom and the United States.

Optical computing is the science and technology of advanced computing for the future, because we are slowly nearing the final limitations of electronic computers. This is because the silicon chips used in current computers have a number of drawbacks: the speed at which electrons can travel through silicon is restricted to  $5 \times 10^5$  m/s; also, it is already becoming more and more difficult to etch ever narrower paths into the silicon chips (which, incidentally, increase the risk of cross-talk); and finally, as they shrink, it becomes harder to keep them cold and operating properly.

Until the Mitsubishi breakthrough, the only hardware developed consisted of (relatively) simple bistable optical devices (BODs), also called transphasors. The Japanese have succeeded in developing a practical optical bonding technology, so that the device they have made consists of many transphasors bonded three-dimensionally and constructed, with a number of other (electronic) components on to a GaAs substrate measuring only  $3 \times 3$  mm. If these initial reports are substantiated, it appears that the Japanese have succeeded in producing the first building brick for a single-board optical computer.

\* \* \*

## LET THE (CABLE) VIEWER BEWARE!

Although it's early days yet, worrying reports reach us from readers all over western Europe in connection with Sky television programmes. It appears that until the Sky programmes were beamed down from the Astra satellite, they had the same sort of variety that viewers in Britain now enjoy: not brilliant, but a pleasant addition to other available channels. Now, however, although these viewers pay for their cable services, they have had these family programmes taken away from them without explanation or apology (or, indeed, money back).

The programmes they enjoyed from time to time have been replaced by sport, sport, and more sport for the whole of the evening. Now, even the most fanatic sports enthusiast does not want to watch sport for seven hours a day, seven days a week, and this applies even more so to younger and female viewers.

If paying viewers in Europe can be treated so shabbily, what will be stopping the Sky management from doing so in Britain one day? After all, from the European experience it appears that no reasons or apologies need be given.

We feel that, on the face of it, the Sky management have made a very grave psychological error, which must cause advertisers to tear their hair out in exasperation. Just when their efforts over the past year or so were beginning to bear fruit, television audiences in Europe appear to be deserting Sky in droves. What a pity that all the promises inherent in the new technology have so far resulted in so little.

## ELECTRONICS SCENE

### New standard control language

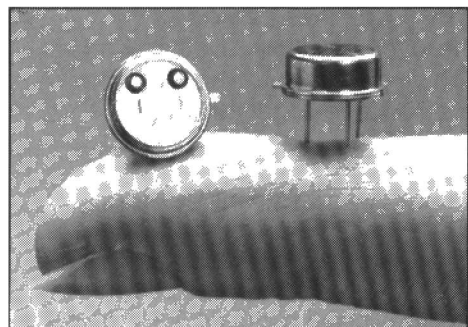
A new high-level control language for intelligent processor-based peripherals in computer bus systems has been announced. Called CLIP, the language is offered as an independent international standard to simplify the use and design of parallel-processing computer systems. Developed jointly by Arcom and British Telecom, CLIP offers system designers major benefits. These include simpler programming to implement distributed-intelligence computer architectures, shorter design cycles, and generally improved control flexibility. Although the language was developed primarily to advance the STE/IEEE-1000 bus, it is equally applicable to other buses such as VME.

A specification document and an application guide with advice in implementing CLIP is available at £15 from Arcom Control Systems • Units 8-10, Clifton Road • CAMBRIDGE CB1 4WH (Tel. 0223 411200) or from British Telecom Microprocessor Systems • BT Research Laboratories • Martlesham Heath • IPSWICH IP5 7RE (Tel. 0473 642933).

### SAWs for Radio Remote Control

Surface Acoustic Wave resonators are fabricated by applying metal structures to the polished surface of piezoelectric single crystals. They are increasingly in demand as frequency-determining components in oscillator circuits, but the latest trend is their use in the radio control of garage doors, car doors and alarm systems. Compared with remote control with ultrasound or infra-red light, greater distances (up to 30-50 metres) can be covered reliably by radio control.

RF remote control is particularly reliable and immune from interference, but it is also very sensitive to the slightest detun-

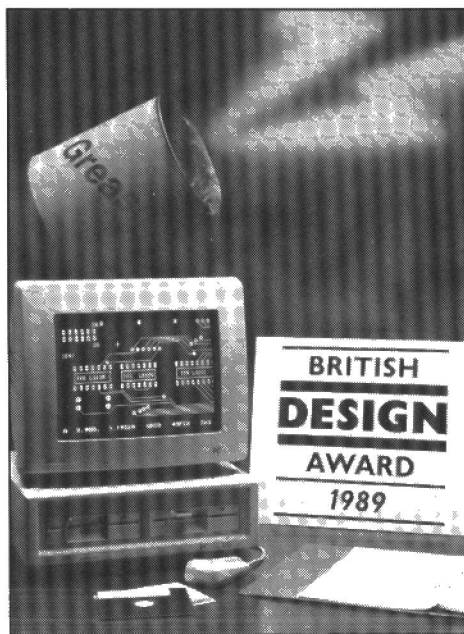


ing effects. For instance, the capacitance of the human hand holding the remote control unit is sufficient to detune the built-in LC networks and shift the fre-

quency. The use of a SAW resonator, which is housed in an hermetically sealed metal case obviates this annoying drawback and will keep the radiated signal spot on frequency at all times. A range of over thirty different SAW resonators is available from Siemens and their appointed distributors.

### British Design Awards

Several electronics and computer firms were among the sixteen winners of the 1989 British Design Awards announced on 31 January. They were: Nautech Ltd for the Autohelm electronic hand bearing compass; ITM Ltd for the Deltascreen projector screen; Toby Churchill Ltd for the Lightwriter SL1 communications device for people who cannot speak; JBS Computer Systems Ltd for Multiview, software that turns the UNIX<sup>TM</sup> computer operating system into a simple and popular tool for general business users; Number One Systems Ltd for the Easy PC programme for the design of printed-circuit boards.



### Intelligent Signal Processors

A range of intelligent signal-processing units from Protech Instruments provides an innovative approach to signal conditioning by its use of a microprocessor set by a portable programmer to eliminate model variation due to function and range.

The processors in the *Sapphire* range will accept a variety of input types and ranges within their particular class: thermocouple, resistance, or general process signals. Each model will linearize as necessary and provide a standard high-level output and two alarm or control signals.

The company can also supply a reduced-function monitor for use by personnel

not authorized to make changes to the chosen parameters, and a calibrator with additional facilities for the adjustment of factory-set calibration data.

Protech Instruments & Systems Ltd • 241 Selbourne Road • LUTON LU4 8NP • Telephone 0582 596181.



### Human body computer modelling

The shape and proportions of the human body can be analysed and stored in a computerized body-modelling and information system developed by Axis Software.

The system, which can be run on most IBM PC compatible computers and graphics work stations, consist of five functions: data collection; model building; model measurement; model manipulation; and a data base.

The surface model of the body is built from a series of triangular facets. The model, viewed as a representation built up on the VDU screen, can be seen from any angle. The model can be manipulated by a simple interactive on-screen process and a graphically indexed data base is stored against all models, allowing rapid analysis of the collected data.

Axis Software Systems Ltd • Park House • 88-102 Kingsley Park Terrace • NORTHAMPTON NN2 7HJ • Telephone 0604 720477.

### Network Quality Analyser

Logic Replacement Technology's *Network Quality Analyser* is claimed to be the first instrument that can make quality measurements on an Ethernet<sup>TM</sup> network. This makes preventive maintenance possible by anticipating where faults are likely to occur. Because of error-correction and rerouting of signals around a network faults can accumulate unnoticed until there is a major breakdown.

The device may be plugged into a node of a live network and can carry out its analysis without affecting the function of the network.

Logic Replacement Technology Ltd • Arkwright Road • READING RG2 0LU • Telephone 0734 311055.

## Digital network control centre

The control centre for London's digital telephone network, recently opened by British Telecom, is equipped with the world's most modern facilities for pinpointing potential trouble spots and taking swift action before service to customers becomes affected.



## Thin film recording heads increase information storage

Researchers at Plymouth Polytechnic's electrical and electronic engineering department have achieved a major increase in electronic information storage capacity by applying advanced techniques to the record/playback head of the ordinary cassette recorder.

Current cassette recorders can cope with a maximum of four tracks on a standard-width cassette. With the use of micro-thin film structures fabricated by high-resolution photolithography, 18-track recording/playback heads have been produced in the clean room.

Combining proven mechanics with the latest electronic technology has resulted in a dramatic increase in the information storage capacity of magnetic tape. The head is so sensitive that recording and playback speeds previously thought to be unobtainable have been achieved, making tape competitive with disc systems.

The technology also has another application. Its sensitivity is such that it can detect patterns and variations in the earth's magnetic field. A prototype compass for use on ships and aircraft has already been demonstrated.

## EUTELSAT confirms transponder reservations

EUTELSAT, the European Telecommunications Organization, has finalized reservation agreements, backed by non-refundable deposits, for the allotment of 49 EUTELSAT II transponders. The organization is currently also finalizing the allocation plan of the transponders on the first four EUTELSAT II medium-power satellites.

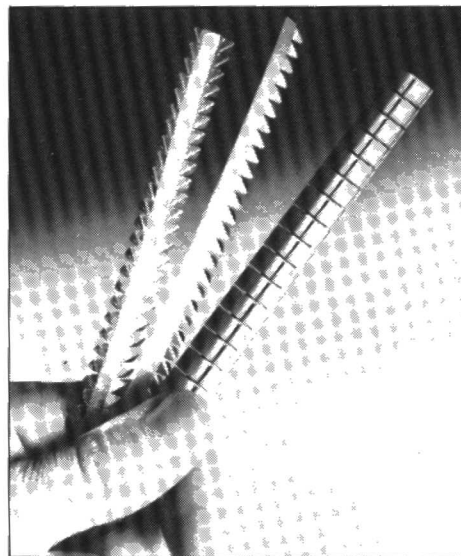
Users of EUTELSAT II capacity will include British Satellite Broadcasting (BSB), holder of the United Kingdom franchise to operate a high-power Direct Broadcast Satellite and a licence for point-to-multipoint satellite services within the UK. BSB has committed itself to a five-year contract for a transponder on a EUTELSAT II satellite.

## European Electronics Week

British Electronics Week will get a change of title and venue in 1991. The event will then be named *European Electronics Week* and move to the redeveloped Earls Court Exhibition Centre in London.

## RF Interference suppression

Border Precision Services have developed an RFI-suppression strip that sells at half the price of rival products. The strips are made in standard shapes or to customer specification. They are



made from beryllium-copper alloy which is available plated with tin or nickel.

Further information from Border Precision Services • Pinnacle Hill Industrial Estate • KELSO TD5 8DW • Telephone 0573 24941.

## BT expands into USA

British Telecom is expanding its interest in the fast-growing mobile communications market by a significant strategic investment in McCaw Cellular Communications Inc.

• McCaw owns or has an interest in some 130 cellular telephone operations throughout the United States. It is by far the largest cellular telephone company in the United States as measured by the number of persons situated in the cellular operating locations it already

# ELECTRONICS SCENE

owns or has the right or obligation to acquire.

The size of the US cellular market is currently about 2 million customers and continues to display exceptionally strong growth.

## Network integration

A data communications computer system that offers a solution to the increasingly wide variety of 'boundary' problems that occur when integrating multi-vendor, multi-protocol computer systems is available from HTEC.

The *Darwin System 5000* contains an expandable multi-processor architecture, based on BMEbus technology, and is tailored for data communications. The hierarchical multi-processor hardware architecture is on three levels and is controlled entirely by software, which makes it easy for the user to tailor the system to an almost unlimited range of applications.

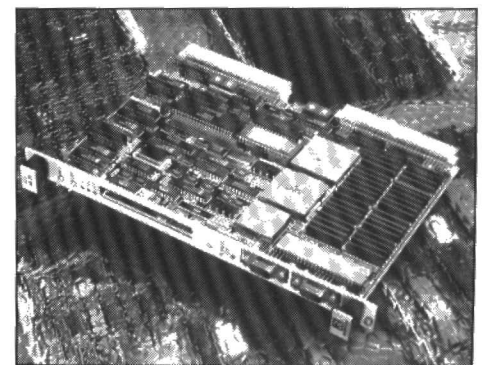
A library of standard softblocks is available that covers most standard requirements.

Further information from HTEC Ltd • 303-305 Portwood Road • SOUTHAMPTON SO2 1LD • Telephone 0703 581555.

## High-speed real-time processing

A multi-faceted, powerful processor board with a variety of applications in systems that require significantly increased processing power and throughput has been developed by Radstone Technology.

The 68-31 is a high-speed VMEbus processor board based on the 32-bit MC68030 microprocessor that offers complete compatibility with the VSB (VME Subsystem Bus) specification. It is ideal for highspeed real-time systems and UNIX multiprocessor systems, while the VSB interface allows for the construction of complex systems.



Further information from Radstone Technology PLC • Water Lane • TOWCESTER NN12 7JN.

# THE DIGITAL MODEL TRAIN — PART 3

by T. Wigmore

In Part 2 we described the background and design of a locomotive decoder and a two-rail adaptor. This month's instalment is dedicated primarily to the construction of those units, but it will also describe a modification to the decoder involving a different decoder chip.

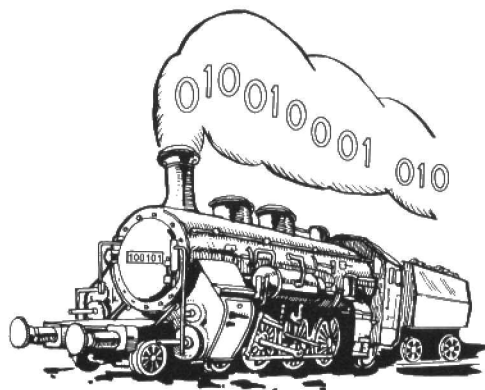
As we have seen last month, the decoder is designed in surface mount technology (SMT). It is, however, impossible to obtain all components as SMT types. Some ICs, for instance, depend for cooling on their housing and if this becomes too small, a heat sink has to be used, defeating the object of the exercise. Therefore, the decoder is a hybrid circuit. It uses a double-sided PCB that is populated at one side with conventional components and at the other with SMT components.

## Soldering surface-mount components

Working with surface-mount (SMT) components requires rather more dexterity, patience and accuracy than working with conventional components. SMT components must be soldered direct to the printed-circuit board (PCB): IC holders, for instance, are no longer required. Because of that, it is essential that during soldering appropriate precautions are taken to ensure the absence of any electrostatic charges (earthed working surface and soldering bit, for example).

The soldering iron should be rated at about 15–18 W, have temperature control and a fine-pointed bit.

One of the first things that strikes one on a first acquaintance with passive SMT components is that most of them no longer show their value. This makes it essential not to remove them from their packing until they are really required. Apart from very thin solder, there is also a special solder dispenser on the market that is ideal for soldering SMT components. A new aid is solder in a syringe. This consists of small granules of lead-tin alloy suspended in a semi-liquid paste. When this paste is applied to the solder pad(s), the component terminal(s) may be pressed into the paste, after which it only requires a touch of the hot soldering bit to give a clean joint.



Soldering ICs is done in very much the same way. Note, however, that SMD ICs do not have the usual identification of pin 1. This is located at the most oblique side of the device (see also Fig. 20).

## Construction

The ready-made printed-circuit board consists of four sections; two locomotive boards (double-sided, but not through-plated) and two two-rail adaptor boards (single-sided) as shown in Fig. 18a and 18b respectively. Construction should be started with cutting the PCB into these four sections.

Determine the voltage for the head and tail lights. As stated in Part 2, the standard voltage for the lights is 10 V, which is perfectly satisfactory for 12-V or 16-V bulbs. If the higher supply of 20 V is needed (because 24-V bulbs or two 12-V bulbs in series are used), a hole of 0.8–1 mm dia. must be drilled in the board for pin 9 of IC<sub>5</sub>. Also, in that case, the through-connection from one side of the board to the other, coinciding with pin 2 of IC<sub>3</sub> must NOT be made.

Mount the (only) wire link to the left of IC<sub>1</sub> and the four through connections shown in Fig. 19a (with the aid of short lengths of equipment wire). Cut these wires as close as possible to the board, particularly where later IC<sub>1</sub> and IC<sub>5</sub> will be located, except beside pin 8 of IC<sub>1</sub>, which should protrude 3–4 mm at the

SMT side.

Select the wanted locomotive address with the aid of Table 3 and install this as shown in Fig. 19b. It is possible to change this afterwards but, owing to the presence of IC<sub>1</sub>, that will then be a tricky operation.

Solder IC<sub>2</sub> and IC<sub>3</sub> at the SMT side of the board. Pins 8 of IC<sub>2</sub> and 2, 4 and 12 of IC<sub>3</sub> coincide with a through connection yet to be made. Bend these pins with a pair of small pliers so that they drop readily into the relevant holes. Before soldering, add a short length of equipment wire that can be soldered at the non-SMT side as well (see Fig. 19c). Note that when a lamp voltage of 20 V is used, the through connection at pin 2 of IC<sub>3</sub> must NOT be made.

Mount all components, except the two ICs and D<sub>9</sub>, at the non-SMT side of the board. Some conventional components need, none the less, be fitted as if they were SMT types: D<sub>1</sub>, D<sub>2</sub> (if a 1N4148 is used), D<sub>8</sub> and the anode of D<sub>10</sub>. Bend the terminal wires of these components sharply near the body and cut them close to the body. If the two-rail adaptor is going to be used, the cathode of D<sub>7</sub> should protrude about 3 mm at the SMT side: later this will be used as through connection with the adaptor. Capacitors C<sub>4</sub> and C<sub>5</sub> (beware of the polarity) are bent at right angles over R<sub>8</sub> and D<sub>1</sub> respectively as shown in Fig. 19d.

Circuits IC<sub>1</sub> and IC<sub>5</sub> must be soldered direct (no holder) to the board. A number of pins must be shortened, because they must not protrude through the board: pins 1, 2, 3, 4, 9 and 11 of IC<sub>1</sub>, and pins 1, 7, 9 (not with 20 V lamp voltage), 11 and 14 of IC<sub>5</sub>. The other pins are soldered at both sides.

Mount D<sub>9</sub> at the non-SMT side.

Finally, solder all components at the SMT side of the board. Note that this side also has to house the four (non-SMT) free-wheeling diodes, D<sub>3</sub> to D<sub>6</sub>. The terminals of these diodes, except the cathodes of D<sub>3</sub> and D<sub>4</sub>, should be soldered direct to the board.

## Parts list

## LOCOMOTIVE DECODER

All parts surface mount assembly except when marked +.

Resistors ( $\pm 5\%$ ):

R1 = 12K

R2; R4; R6 = 100K

R3; R7 = 47K

R5 = 270K

R8 = 2K7

## Capacitors:

C1 = 3n3

C2 = 10n

C3 = 470p

C4 = 10 $\mu$ ; 25 V; tantalum +

C5 = 47 $\mu$ ; 6V3; tantalum +

## Semiconductors:

D1 = 5V1; 400 mW zener diode +

D2 = BAV100

D3...D6 incl. = 1N4148 +

D7...D10 incl. = 1N4001 +

IC1 = MC145029 (Motorola) +

IC2 = 4060

IC3 = 4585

IC4 = 4001

IC5 = L293 (SGS) or LM 18293 (National Semiconductor) +

## TWO-RAIL ADAPTOR

All parts surface-mount assembly

Resistors ( $\pm 5\%$ ):

R1; R2 = 1M0

R3 = 10K

R4 = 270K

## Capacitors:

C1 = 1n0

C2 = 15n

C3 = 100p

C4 = 47n

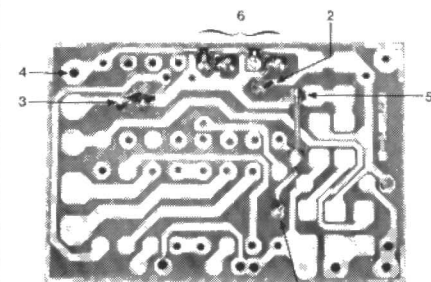
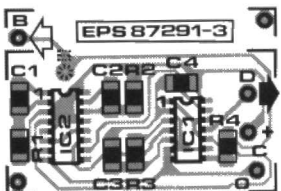
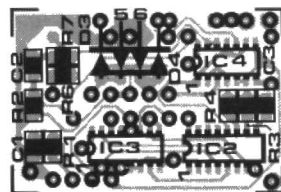
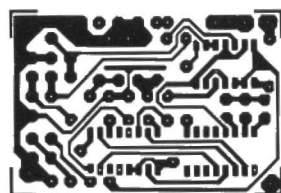
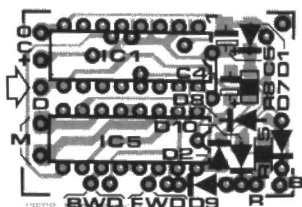
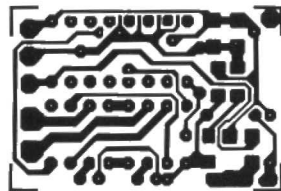
## Semiconductors:

IC1 = 4030

IC2 = 4538

## Miscellaneous:

PCB Type 87291-2/3 (cut in 4 for 2 two-rail adaptors and 2 locomotive decoders).



1...4 = through connections to be made  
5 = wire link  
6 = address setting (see Fig. 19b)

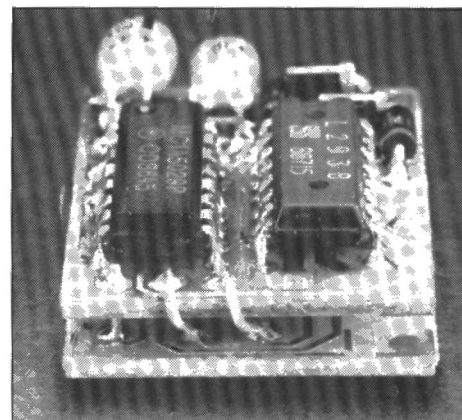
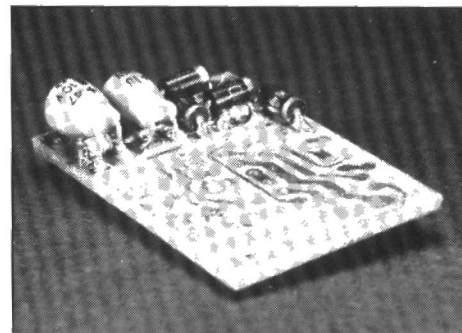
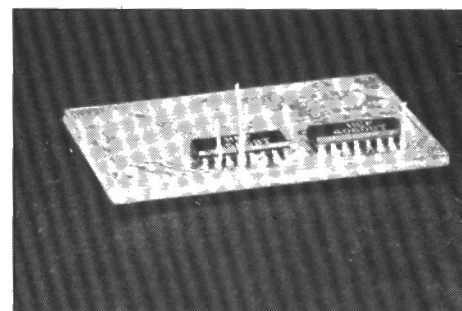
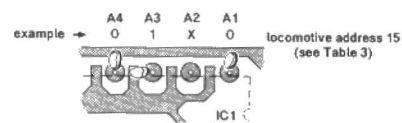


Fig. 18. Layout and track side of the double-sided (not through-plated) decoder board (a) and those of the single-sided two-rail adaptor board (b).

This concludes the construction of the locomotive decoder board.

Construction of the single-sided two-rail adaptor board is straightforward. This board is populated with SMT components only.

Before the two boards are sandwiched (if the adaptor board is used), they should be tested together. There are four electrical connections between them that,

for test purposes, should be made before some of the wires are cut short. These are: B (made with the cathode terminal of D7 that has been kept long for this purpose); earth (made with the through connection adjacent to pin 8 of IC1); the positive supply line and the data line. The last two should be made with short lengths of equipment wire — see Fig. 19e.

Fig. 19. How to make the through connections (a), but note that only three are made in this photograph; (b) the address setting of pins 1—4 of IC1; (c) the through connections of IC2 and IC3 to the other side of the board; (d) C4 and C5 are bent at right angles across R8 and D1 respectively, while some other components, such as D1, are mounted as SMT elements; (e) the decoder and two-rail adaptor boards are sandwiched.

## Installation

The locomotive decoder can be used with d.c. as well as with a.c. locomotives. Actually, the motor of an a.c. locomotive is generally connected as a d.c. motor. The way this is done is shown in Fig. 21. The general wiring diagram of an a.c. motor (here a Marklin type) is shown in Fig. 21a. It is seen that it is connected as a series motor whose stator winding has a centre tap. Which half of the stator winding is used at any one time is determined by the position of the change-over relay (in some models this relay also switches over the lights).

As already discussed, this change-over relay must be removed from Marklin locomotives. Figure 21b shows how two diodes in series with the disconnected terminals of the stator winding convert the a.c. motor to a d.c. motor. The direction of rotation is then dependent on the polarity.

The two motor terminals are connected to the motor output of the decoder (to the right of IC5). The decoupling components, L1, C1, C2, may be retained, but C2, which was connected to earth must now be connected to the '0' line of the decoder.

D.C. motors can be connected to the motor terminals of the decoder without any modifications.

There are various ways of connecting the lights and some of these are shown in Fig. 22. For instance, they may be switched in the positive line (22a) or in the negative line (22b). The former is preferable in view of the somewhat lower dissipation in IC5.

If the lights are required to be independent of the direction of travel, the lamps are connected in series, two by two, direct to the rail voltage as in Fig. 22c. If the lights are preferred in parallel, but are not suitable for 20-V operation, they may be connected to the two La terminals (Fig. 22d). The voltage for the lights must then be set to 10 V as discussed earlier.

When Marklin locomotives are used, it is important that if the lights are connected to the La terminals on the decoder there is no connection between them and the chassis of the locomotive. This means that either the lamp holders must be of the insulated type or the lamps must be connected via an additional diode as shown in Fig. 22e. A drawback of the diode solution is that the lights often have no constant brightness and may flicker from time to time.

If Marklin locomotives are used and the lights are required to be operated independently of the direction of travel, they should be connected as shown in Fig. 22f. They need not be isolated from the locomotive chassis. The brightness may be set by giving the series resistor an appropriate value.

The motor must also be electrically isolated from the locomotive chassis, but

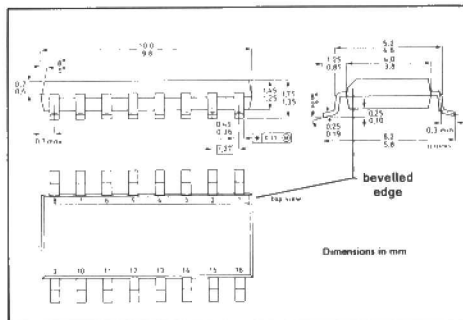


Fig. 20. Pin 1 of an SMD IC is located at the most oblique side.

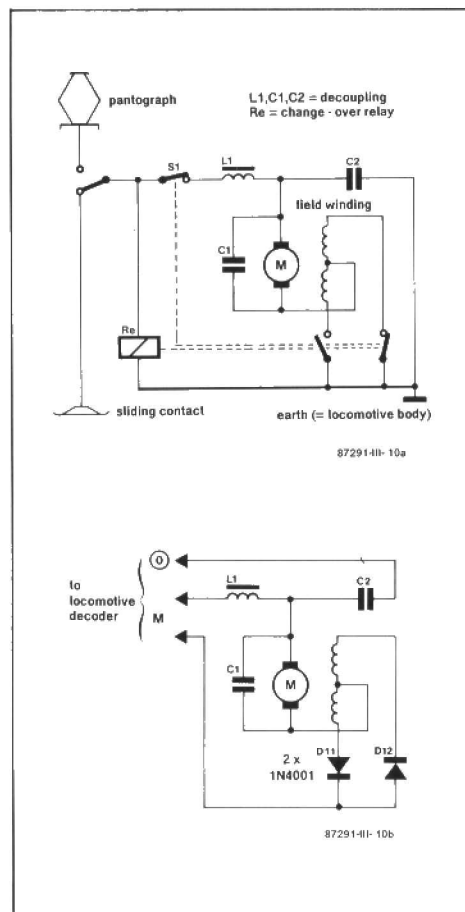


Fig. 21. Circuit diagram of the Marklin motor connections (a); this a.c. motor may be converted for d.c. operation as shown in (b).

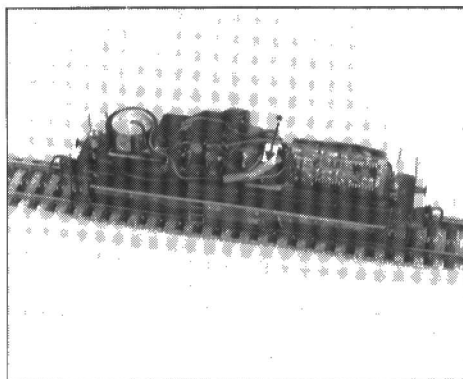


Fig. 23. Decoder (without two-rail adaptor) installed in a Marklin locomotive; the buffer capacitor, where used, is fitted in the back of the locomotive. The arrow points to the shrink-sleeved diodes that enable the polarity of the stator field to be reversed.

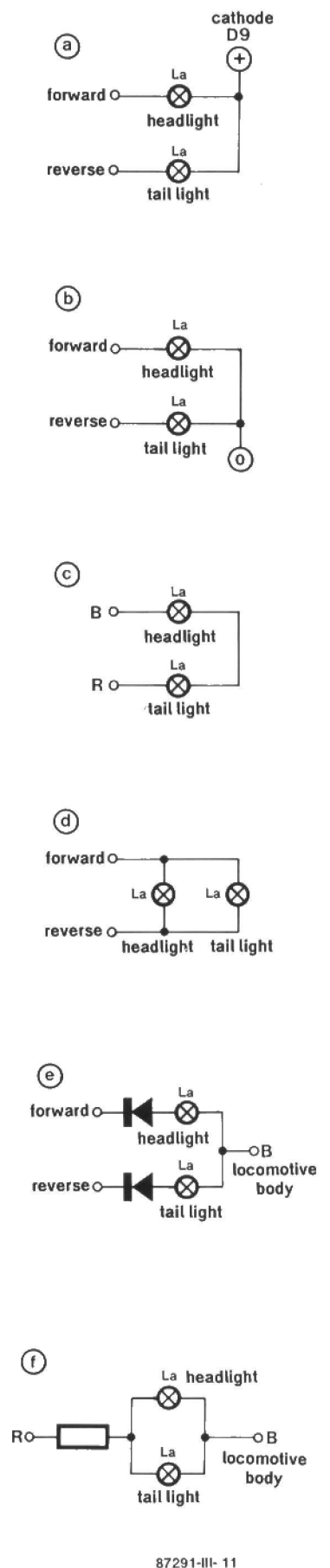


Fig. 22. Various possibilities of connecting the lights.

Table 3.

number of loco- motive	address				number of loco- motive	address			
	A1	A2	A3	A4		A1	A2	A3	A4
01	1	0	0	0	41	X	1	1	1
02	X	0	0	0	42	0	X	1	1
03	0	1	0	0	43	1	X	1	1
04	1	1	0	0	44	X	X	1	1
05	X	1	0	0	45	0	0	X	1
06	0	X	0	0	46	1	0	X	1
07	1	X	0	0	47	X	0	X	1
08	X	X	0	0	48	0	1	X	1
09	0	0	1	0	49	1	1	X	1
10	1	0	1	0	50	X	1	X	1
11	X	0	1	0	51	0	X	X	1
12	0	1	1	0	52	1	X	X	1
13	1	1	1	0	53	X	X	X	1
14	X	1	1	0	54	0	0	0	X
15	0	X	1	0	55	1	0	0	X
16	1	X	1	0	56	X	0	0	X
17	X	X	1	0	57	0	1	0	X
18	0	0	X	0	58	1	1	0	X
19	1	0	X	0	59	X	1	0	X
20	X	0	X	0	60	0	X	0	X
21	0	1	X	0	61	1	X	0	X
22	1	1	X	0	62	X	X	0	X
23	X	1	X	0	63	0	0	1	X
24	0	X	X	0	64	1	0	1	X
25	1	X	X	0	65	X	0	1	X
26	X	X	X	0	66	0	1	1	X
27	0	0	0	1	67	1	1	1	X
28	1	0	0	1	68	reserved			
29	X	0	0	1	69	0	X	1	X
30	0	1	0	1	70	1	X	1	X
31	1	1	0	1	71	X	X	1	X
32	X	1	0	1	72	0	0	X	X
33	0	X	0	1	73	1	0	X	X
34	1	X	0	1	74	X	0	X	X
35	X	X	0	1	75	0	1	X	X
36	0	0	1	1	76	1	1	X	X
37	1	0	1	1	77	X	1	X	X
38	X	0	1	1	78	0	X	X	X
39	0	1	1	1	79	1	X	X	X
40	1	1	1	1	80	0	0	0	0

that is normally the case anyway. The above explanations should ensure that the conversion of d.c. motors for use on a Marklin system should not present any problems. Note, however, that the locomotive must be provided with a sliding contact.

Connecting the decoder and two-rail adaptor to d.c. locomotives for two-rail systems should not present any difficulties. The B(rown) and R(ed) terminals may be connected to the wheel contacts at will, since the decoder is not polarity-conscious.

## Testing and faultfinding

It is advisable to test the decoder in association with the locomotive before installing it. In the following it is assumed that at least a Marklin digital HO system is available, that is, one Central Unit, one Control 80, and one 16-V mains transformer. Later in the series, this may also be the Elektor Electronics Digital Model Train System (EDiTS). Connect the brown and red wires of the HO system to the B and R terminals respectively on the decoder. Provided that the address keyed in on Control 80 corresponds to the address set on the

decoder, the locomotive should react to an adjustment of the speed regulator. If it does not, check that the locomotive address has been set correctly (Table 3) and that the supply for the logic circuits is 4.5–5.5 V.

If these are correct, make sure that pin 12 of IC<sub>2</sub> is logic 0 and that the oscillator operates (this is indicated by the logic level at pin 1 of IC<sub>2</sub> changing every second).

If all these are in order, measure the average output voltage at pin 1 of IC<sub>5</sub>: it should be possible to vary this with the Control 80 speed regulator between 0 V and just below the level of the supply voltage to the logic circuits. If this is not possible, check whether the logic level at pin 5 of IC<sub>1</sub> changes when the function key on Control 80 is operated.

If all these are correct, the fault lies in IC<sub>1</sub> (incorrect address or baud rate).

If the voltage at pin 1 of IC<sub>5</sub> can be varied, but the locomotive does not move, check whether pin 2 of IC<sub>5</sub> is logic 0 and pin 7 of IC<sub>5</sub> is logic 1 (or the other way round, depending on the position of the function key). If this is in order, the fault lies in IC<sub>5</sub>, or the motor is connected incorrectly, or the motor is (mechanically) impeded.

In this context, note that the outputs of IC<sub>5</sub> are not short-circuit proof: care should, therefore, be taken when lights and motor are connected. Thermal-overload protection is provided.

If the decoder operates correctly, but the last received data are lost rapidly (in spite of the external buffer capacitor) when the supply is switched off (emergency control), too high a current to the logic circuits is indicated. A possible cause of this is a short-circuit between two logic outputs or between such an output and a supply line (check the non-used outputs of IC<sub>2</sub> as well), or a zener diode with a very high leakage current. Note that solder flux is electrically conductive and may, therefore, be responsible for a short-circuit.

Another possible cause of too high a current may lie in the particular type of 4060 chip. Although in all makes the outputs are reset, in some of them the internal oscillator is not switched off.

## Installation

It is advisable to glue (two-component epoxy resin or super glue) a small rectangular piece of aluminium across the decoder (IC<sub>1</sub>-IC<sub>5</sub> side): this will act as a heat sink for IC<sub>5</sub>. This circuit can get pretty hot during driving, but that is normal. As long as you can put your finger to it without getting burnt, nothing untoward is happening. It cannot be too strongly emphasized to take care that there is no short-circuit between the decoder and the locomotive chassis.

The use of an external buffer capacitor

depends on the circumstances. It is essential when tracks with conventional block protection are used, that is, those that stop the locomotive by removing the voltage from the rails.

If the locomotive is stopped by switching the rails to a lower voltage (say, 8 V), an external buffer capacitor is not required. Although the charging current of the buffer capacitor is some 200 times higher than its discharge current, it may take a short time after the power is applied to the track before the decoders are ready for operation. This time lag depends on the capacitance of the buffer, and it is, therefore, not advisable to take too large a value for this component — some thousands of microfarads is quite sufficient.

## Sidings and passing loops

A classical problem with two-rail tracks is the short-circuit between the two rails when a passing loop is used. In a conventional system, the loop is electrically insulated. The locomotive moves on to the loop and while it is there the polarity of the rail voltage is changed over. Unfortunately, this also affects the direction of travel of all other locomotives on the track.

The digital system obviates this problem. The loop is again electrically insulated from the remainder of the track. The locomotive moves onto the loop as before, but in this case the polarity of the voltage on the loop is reversed while the locomotive is on the loop. This will not affect the direction of travel, because that is, after all, determined internally and independently of the polarity of the connections.

## Operational hints

As discussed in Part 2, if the decoder is used in conjunction with the Marklin digital HO system, the function switch on Control 80 changes the direction of travel. One Control 80 suffices to control a number of locomotives, but as soon as a change-over from one locomotive address to another takes place, a problem arises. The function of the newly addressed locomotive will be set automatically to 'off'. If this locomotive was previously set to 'reverse', it will suddenly change direction. This is prevented by keying in only the first digit of the new address on Control 80, then pressing the function switch (only if the relevant locomotive is set to 'reverse', of course), setting the speed controller to the position it was when the locomotive to be addressed was last controlled, and only then keying in the second digit of the address.

## Decoder modification

When the design of the decoder was started just about a year ago, availability of the MC145029 chip was assured by Motorola Europe. In spite of that assurance, production of the device was stopped in December 1988. Many constructors will, therefore, find it next to impossible to obtain the chip. For that reason, a modification was designed that is based on the MC145027 (which is also used in the points/signals decoder — see Part 1 — and is, incidentally somewhat cheaper than the MC145029).

In the MC145027, the first five bits are address bits and the other four are data bits, while in the locomotive decoder four address bits and five data bits are required. There is thus a shortage of one data bit: the bit that ensures changeover of direction of travel.

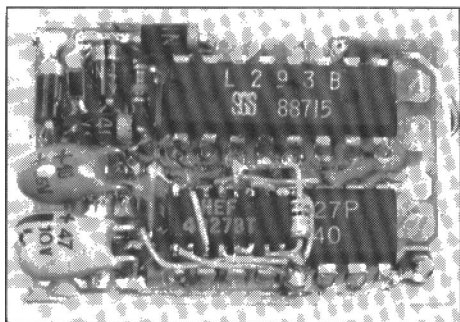


Fig. 24. The decoder board modified to operate with an MC145027 data decoder.

It is thus necessary to effect the change of direction of travel by another means, and this is done by adding a dual J-K bistable (physically glued on top of the MC145027 as shown in Fig. 24 and Fig. 27). This modification makes the change-over of direction of travel compatible with the Marklin system — see Fig. 25.

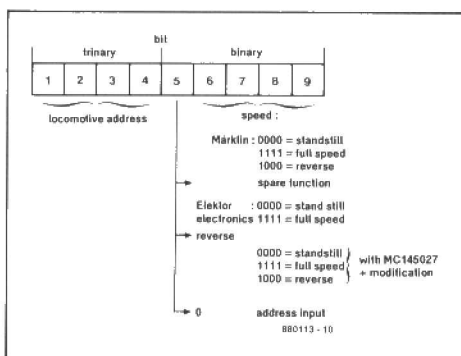


Fig. 25. The modification restores the change of direction of travel to the original Marklin concept.

Parts required for modification  
R9 = 1MΩ (physically as small as possible)  
D13, D14, D15 = 1N4148  
IC1 = MC145027 (in place of MC145029)  
IC6 = 4027 (SMD)

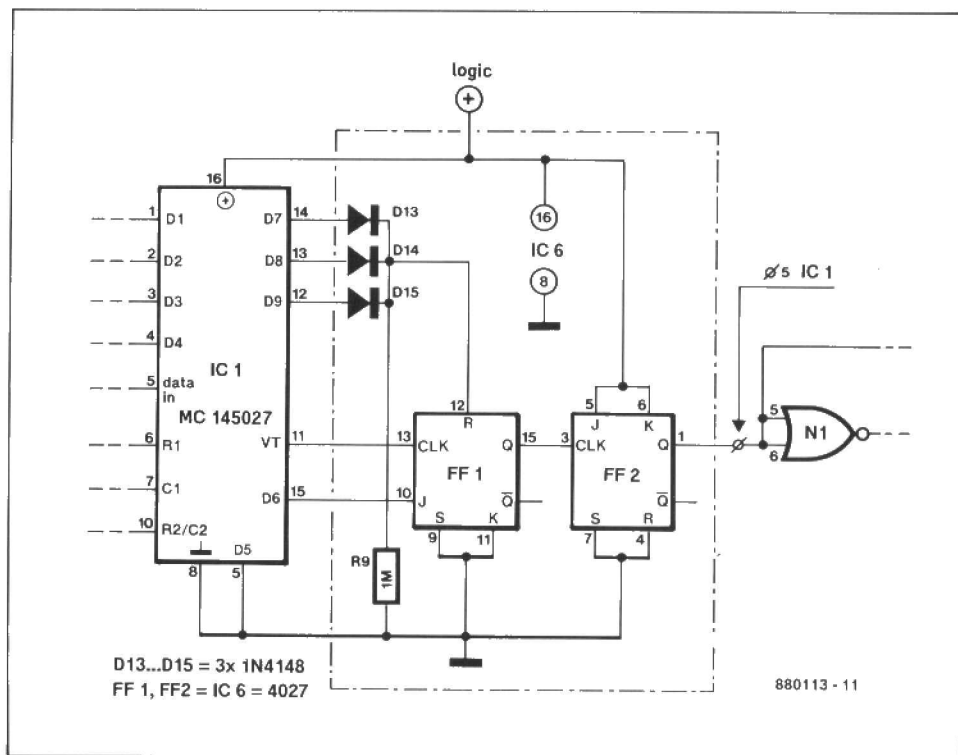


Fig. 26. Circuit diagram of the modification.

The lowest speed-step is decoded and used to clock the switching bistable. This is achieved as shown in Fig. 26.

The unused bistable in the SMT 4027, FF1, is used for decoding the lowest speed-step. It is set when its input is 1000 after which it clocks FF2. Since the J and K inputs of FF2 are strapped together, the logic level of the output of the bistable changes with every clock pulse. It is thus not possible to change the direction of travel two times in quick succession, but that does not occur in practice very often in any case. If, therefore, the direction of travel was changed erroneously, this can only be corrected after FF1 has been reset and this does not happen until D7, D8 or D9

has become logic 1, that is, until the locomotive has travelled a short distance.

The construction of the modification requires dexterity. The pins of the MC145027, like those of the MC145029, are cut short, but pin 5 is bent away from the body slightly to enable it being soldered to the earth track adjacent to the IC1 position.

As stated, glue the SMT 4027 on top of the MC145027 in such a way that pins 1 and 16 of the two ICs coincide.

The anodes of diodes D13, D14 and D15 are bent at right angles, cut short and soldered to pins 14, 13 and 12 respectively of IC1.

The remainder of the wiring is seen in Fig. 27. Use very thin wire (for instance enamelled copper wire or wire with teflon insulation). The output of FF2 (pin 1) is connected to where originally pin 5 of IC1 was connected.

Since pin 5 of the MC145027 is an address input, it is, in principle, possible to control even more than 80 locomotives as originally envisaged. If this pin is connected to the logic + line, the appropriate decoder may be accessed by keying in the locomotive address and pressing the function key. It is possible in this way to control up to 160 locomotives simultaneously.

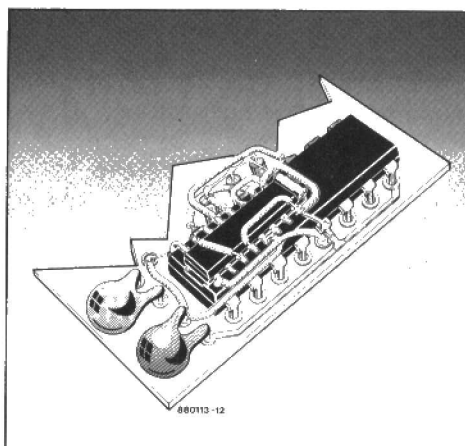


Fig. 27. Adding three diodes and a dual bistable on to the MC145027 requires some dexterity.

# CLASS-D AMPLIFIER

by J. Bareford

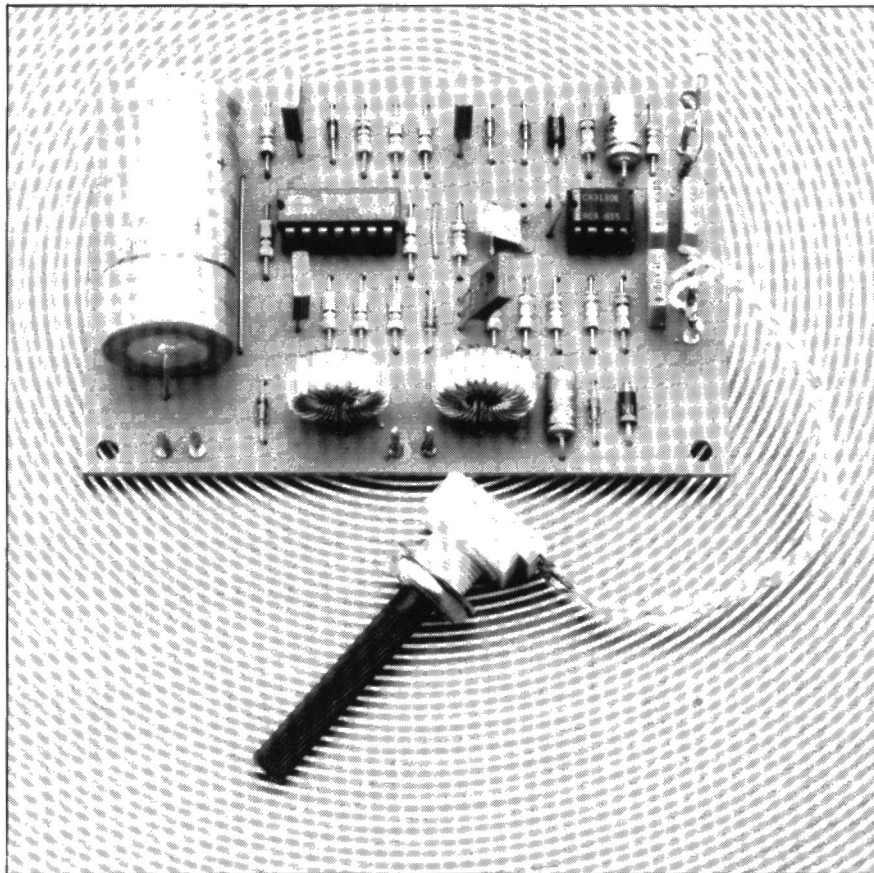
The terms digital amplifier, class-D amplifier, switched amplifier and PWM amplifier all refer to a type of amplifier that converts its input signal into a rectangular signal with variable duty factor. The high efficiency achieved by a class-D amplifier makes it of particular interest for mobile and public address applications, where low distortion is not a prime issue. The AF power amplifier described here works from a 6 V battery, and delivers up to 5 watts. As such, it is eminent for use in, for instance, a megaphone.

A well-known problem with mobile AF amplifiers is that their low efficiency makes it virtually impossible to generate high power levels from a low supply voltage. The amplifier described here has a total efficiency of almost 100% at a distortion level that is tolerable with megaphones and similar P.A. equipment. The basic principle behind the design is

## Pulse-width modulation

Figure 1 shows the principle of pulse-width modulation (PWM): the input signal controls the duty factor of a rectangular signal of a much higher frequency. The on-time of the pulse is proportional to the instantaneous amplitude of the input signal. The sum of the on-time and the off-time — and, therefore the frequency — is, however, constant. Hence, a symmetrical rectangular signal (square wave) is generated in the absence of an input signal.

In order to obtain reasonable sound quality, the frequency of the rectangular wave must be at least twice as high as the highest frequency in the input signal. A simple low-pass filter may then be used for integrating the rectangular signal. The result is a signal that may be used for driving a loudspeaker. The signal conversion is apparent from the lower oscilloscope trace in Fig. 4. The upper trace displays the output signal after filtering, measured across the loudspeaker. The amplitude of the residual



PWM signal superimposed on the sine-wave is small.

## Switches as amplifiers

The basic operation of the PWM amplifier may be illustrated with the aid of the block diagram in Fig. 2. Assuming that the input is short-circuited, switch  $S_a$  charges capacitor  $C_7$  with a current  $I_2$ , until a voltage is reached that corresponds to the upper switching threshold of the electronic switch. This then connects  $R_7$  to ground. Next,  $C_7$  is discharged to the lower switching threshold of  $S_a$ . The resulting square wave has a frequency of about 50 kHz, as determined by  $C_7$  and  $R_7$ .

An AF signal applied to the input of the

amplifier effectively causes the additional current  $I_1$  to proportionally reduce or increase the charge time, and increase or reduce the discharge time. The input signal thus controls (*modulates*) the duty factor of the rectangular signal which appears at the loudspeaker output.

Two further principles are important for the basic operation of the PWM amplifier. First, switch  $S_b$  is controlled in anti-phase with  $S_a$ , and keeps the other loudspeaker terminal at a voltage complementary to that of the PWM signal. This arrangement results in a switching power output stage of the bridge type: the loudspeaker is driven with the full supply voltage at each polarity, so that the

highest possible current consumption is achieved.

The second additional point to note concerns inductors  $L_1$  and  $L_2$ . These integrate the rectangular signal and so make it sinusoidal as seen in Fig. 4. The inductors also serve to suppress harmonics of the 50 kHz rectangular signal.

## High sound levels from a small circuit

The components shown in the block diagram are easily recognized in the circuit diagram of Fig. 3. The input section of the PWM amplifier is formed by a capacitor (or electrostatic) microphone, biased via  $R_1$ , coupling capacitors  $C_1$  and  $C_4$ , a volume control,  $P_1$ , and an

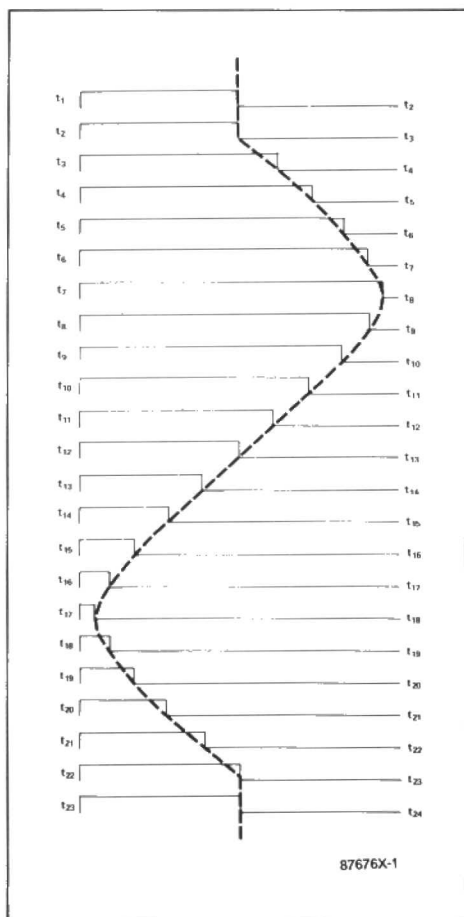


Fig. 1. Conversion of a sine-wave into a pulse-width modulated (PWM) signal.

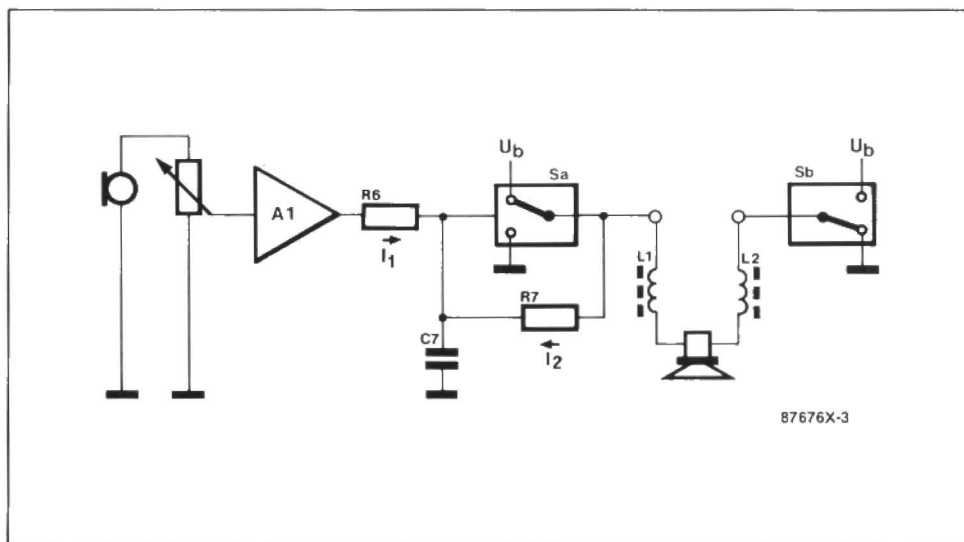


Fig. 2. Block diagram of the class-D amplifier.

amplifier based around opamp A1. The previously discussed switches  $S_a$  and  $S_b$  are formed by electronic switches  $ES_1$  to  $ES_4$  in combination with transistor pairs  $T_1$ - $T_3$  and  $T_2$ - $T_4$ . The part indications for the components that form the PWM generator correspond to those discussed with the block diagram.

The unusually high efficiency of the PWM amplifier is perhaps best illustrated by the fact that the output transistors remain cool under all drive con-

ditions — dissipation in the power output stage is virtually nought.

When selecting practical inductors for  $L_1$  and  $L_2$ , remember that their ability to pass 3 A without becoming saturated is far more important than the actual inductance. The inductors used in the prototype were toroid types salvaged from a lamp dimmer.

Diodes  $D_3$  to  $D_6$  limit the reverse e.m.f. generated by the inductors to a safe

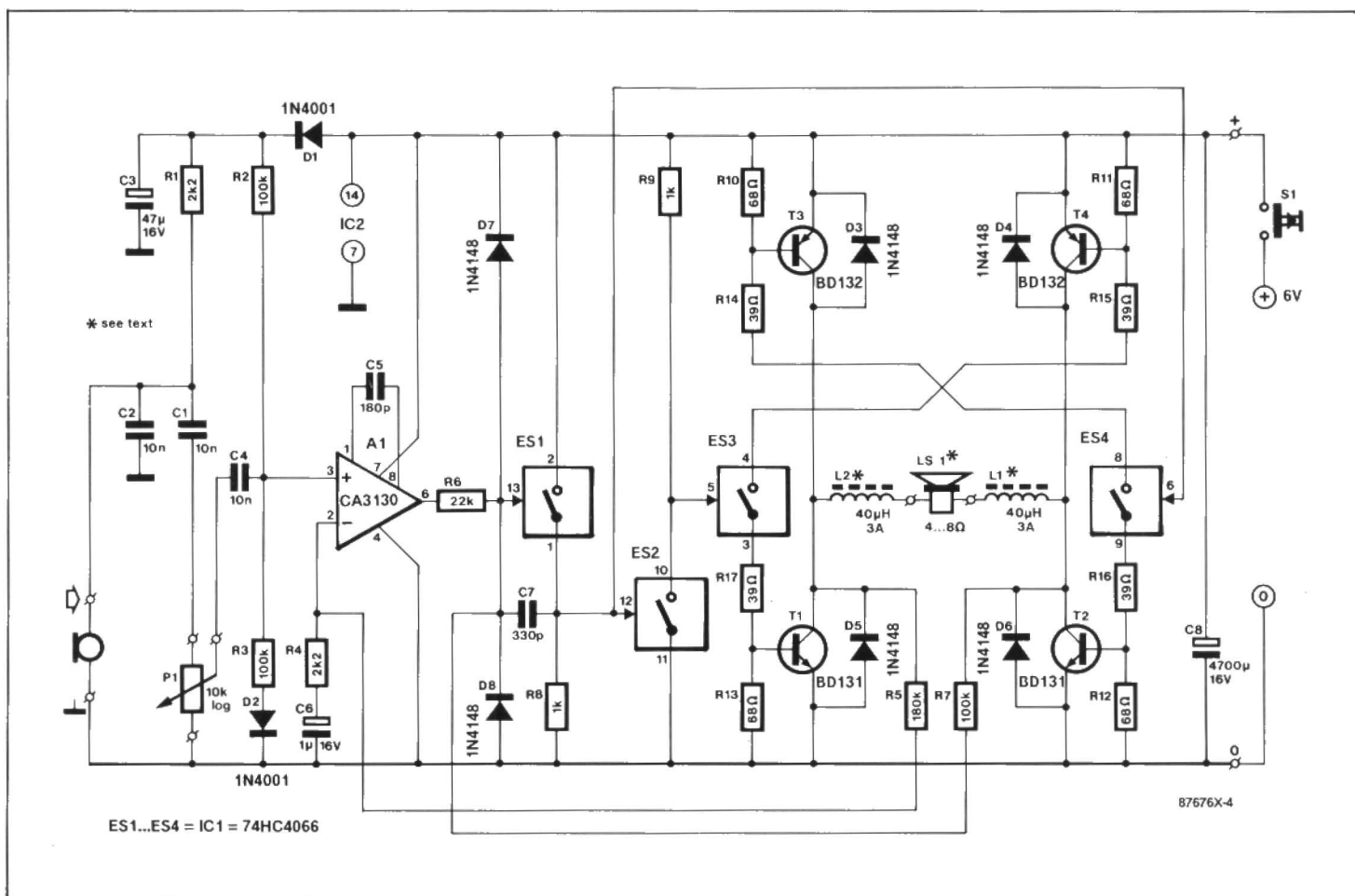


Fig. 3. Circuit diagram of the 4 W class-D amplifier for public address applications.

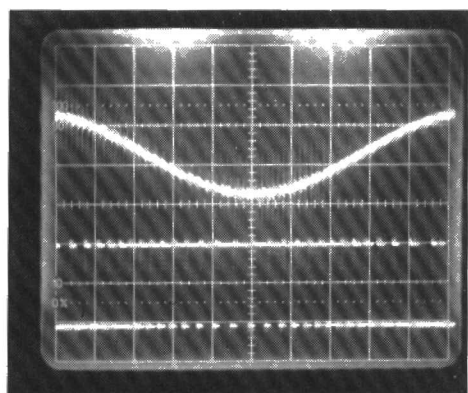


Fig. 4. Sinusoidal output signal (upper trace) and PWM control signal (lower trace).

value. Components  $D_1$ ,  $C_3$ ,  $D_2$  and  $R_3$  provide the non-inverting input of opamp  $A_1$  with a well-filtered potential equal to half the supply voltage. As with a conventional opamp-based amplifier, the voltage gain is set by a negative feedback network. In practice,  $R_4$  and  $R_5$  set

the gain to 83 to ensure adequate microphone sensitivity. When high-impedance signal sources are used,  $R_4$  may be increased accordingly.

Because of the phase shift introduced by  $L_1$  and  $L_2$ , feedback is realized with the aid of the rectangular signal at the collector of  $T_1$ , rather than with the sinusoidal loudspeaker signal. The opamp itself, in combination with  $C_5$ , provides the required integration of the PWM feedback signal. It should be noted that the feedback system reduces the amplifier's distortion, but not, unfortunately, to a level that would make it suitable for applications other than public address. A class-D amplifier with low distortion would require a much higher supply voltage than used here, and would be a fairly complex design. This, in turn, would almost inevitably result in much reduced overall efficiency. The electronic switches in the amplifier must be HCMOS types — a standard CMOS Type 4066 is so slow as to cause

a short-circuit across  $T_1$ - $T_3$  and  $T_2$ - $T_4$ , with the obvious risk of overloading or even destroying the amplifier.

## Bullhorn

The class-D amplifier is preferably used for driving horn-type loudspeakers, since these offer the highest sound pressure for a given power level. The prototype of the amplifier was used in combination with a 6 V battery pack and a pressure chamber loudspeaker. The available 4 watts of output power resulted in a megaphone with an impressive acoustic range.

Four series-connected 1.5 V dry batteries (HP11; C; UM2; Baby) or alkaline monocells provide the supply voltage for the megaphone. When this is used frequently, a rechargeable NiCd or gel-type (Dryfit) battery may be preferred. The maximum current consumption of the megaphone is about 0.7 A, so that an alkaline battery has sufficient capacity for 24 hours operation at full output power. For non-continuous operation, however, a set of dry batteries is perfectly adequate.

Whatever power source is used, the supply voltage for the amplifier should not exceed 7 V, because the HCMOS switches in  $IC_1$  do not operate correctly any more at this level. Fortunately, the absolute maximum supply level for the amplifier is higher at 11 V.

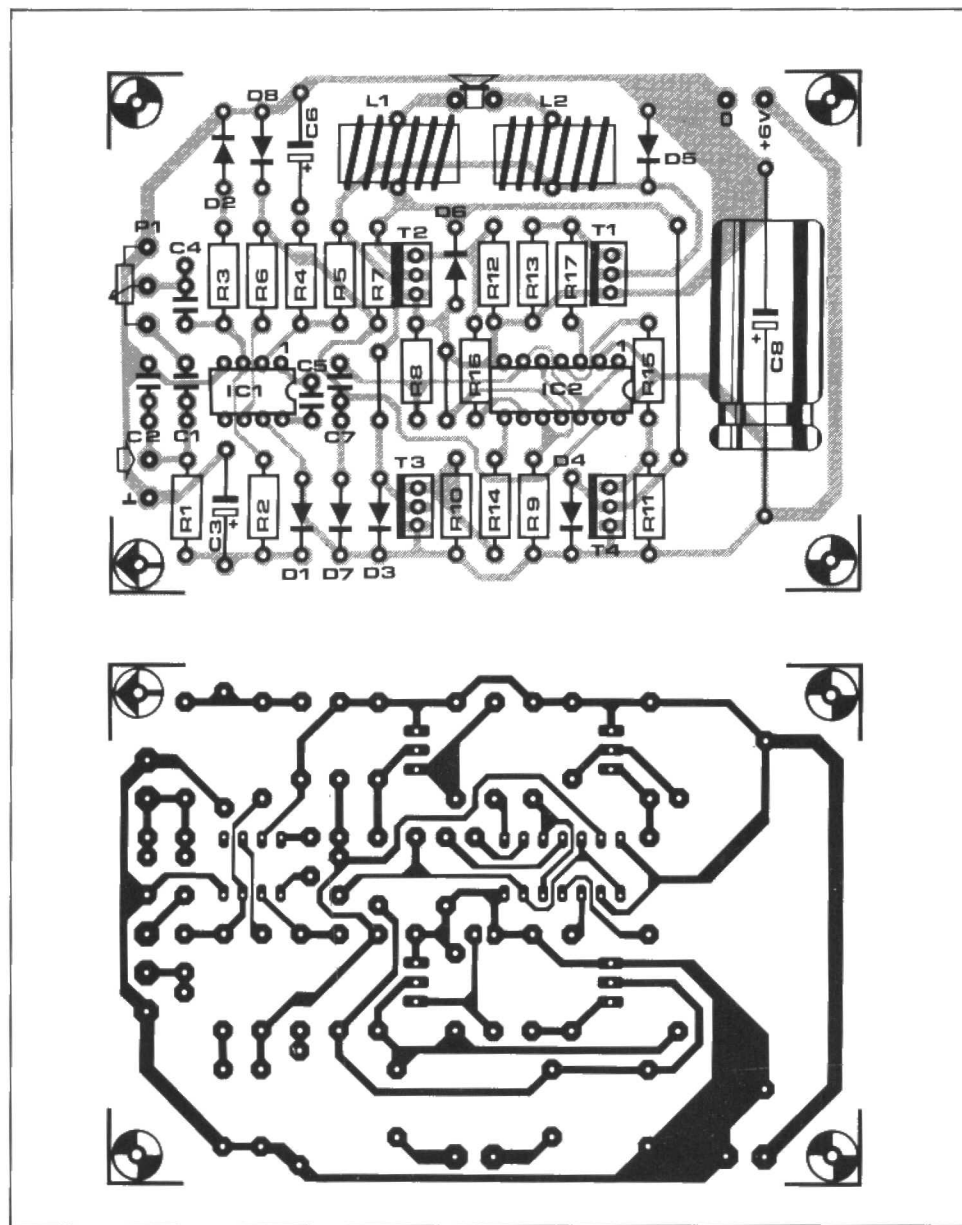


Fig. 5. Printed-circuit board for the amplifier.

### Parts list

#### Resistors ( $\pm 5\%$ ):

$R_1, R_4 = 2K2$   
 $R_2, R_3, R_7 = 100K$   
 $R_5 = 180K$   
 $R_6 = 22K$   
 $R_8, R_9 = 1K0$   
 $R_{10} \dots R_{13} \text{ incl.} = 68R$   
 $R_{14} \dots R_{17} \text{ incl.} = 39R$   
 $P_1 = 10K \text{ logarithmic potentiometer}$

#### Capacitors:

$C_1, C_2, C_4 = 10n$   
 $C_3 = 47\mu, 16V$   
 $C_5 = 180p$   
 $C_6 = 1\mu0, 16V$   
 $C_7 = 330p$   
 $C_8 = 4700\mu, 16V$

#### Semiconductors:

$D_1, D_2 = 1N4001$   
 $D_3 \dots D_8 \text{ incl.} = 1N4148$   
 $T_1, T_2 = BD131 \text{ or } BD226$   
 $T_3, T_4 = BD132 \text{ or } BD227$   
 $IC_1 = CA3130$   
 $IC_2 = 74HC4066$

#### Miscellaneous:

$S_1 = \text{push-to-talk switch.}$   
 $L_1, L_2 = 40\mu H; 3A \text{ toroid suppressor choke.}$   
 $LS_1 = 4 \dots 8R; 10W; \text{waterproof horn loudspeaker.}$   
 Capacitor microphone.  
 PCB Type 87676 (not available through the Readers Services).

# PRACTICAL FILTER DESIGN (4)

by H. Baggott

The previous part in this series discussed the most important low-pass filters. This month we turn our attention to high-pass and band-pass networks. Since these are derived from low-pass sections, we often speak of derived filters.

A high-pass section is derived simply from a low-pass section by substituting  $1/j\omega$  in the transfer function for  $j\omega$ . This is not nearly as complicated as it looks, and is fairly easily realized in practical terms as well. In practice, it means that in a passive filter all inductances are replaced by capacitances and all capacitances by inductances. In an active filter, all resistances and capacitances are interchanged.

The computation of the new components is also simplicity itself. First, calculate the normalized values of all components for the low-pass section, replace the components by their "opposites" and compute the values of the newly required components as follows.

Passive filters:

$$C_{HP} = 1/L_{LP}$$

$$L_{HP} = 1/C_{LP}$$

Active filters:

$$C_{HP} = 1/R_{LP}$$

$$R_{HP} = 1/C_{LP}$$

Once the normalized high-pass filter has been computed in this way, the actual component values are dimensioned for the required cut-off frequencies.

Figures 18, 19, 20, 21, 22 and 23 show the high-pass filters derived from the low-pass sections discussed in Part 3. These are:

- passive type with equal input and output impedances;
- passive type connected to source of negligible internal resistance;
- two-pole active type with voltage follower;
- a filter with a real pole;
- a two-pole filter with variable gain;
- a state-variable filter.

The interchanging of resistances and capacitances does not work in a state-variable filter. This type requires the addition of a summing amplifier that combines the input signal, the band-pass signal and the low-pass signal into a

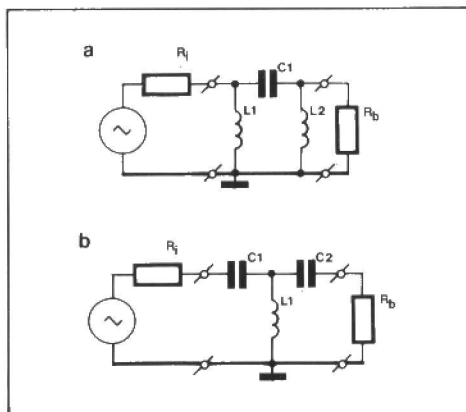


Fig. 18. Passive high-pass filters with equal input and output impedances ( $R_i = R_L$ ): (a)  $\pi$ -type; (b) T-type.

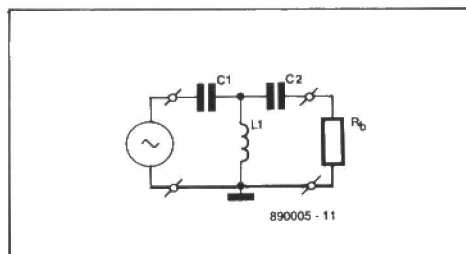


Fig. 19. Passive high-pass filter connected to a source of negligible resistance and terminated in  $R_L$ .

high-pass function. In the case of an odd-order filter, the amplifier is followed by a passive RC filter.

The computation of the various components in a state-variable high-pass filter is carried out as follows. First, calculate the normalized high-pass pair of poles:

$$\alpha' = \alpha/(\alpha^2 + \beta^2) \quad [25]$$

$$\beta' = \beta/(\alpha^2 + \beta^2) \quad [26]$$

The component values are then arrived at:

$$R_1 = R_2 = 1/(4\pi\alpha'C) \quad [27]$$

$$R_3 = R_4 = 1/2\pi C \sqrt{[(\alpha')^2 + (\beta')^2]} \quad [28]$$

$$R_5 = 2\alpha'R / \sqrt{[(\alpha')^2 + (\beta')^2]} \quad [29]$$

$$R_6 = AR \quad [30]$$

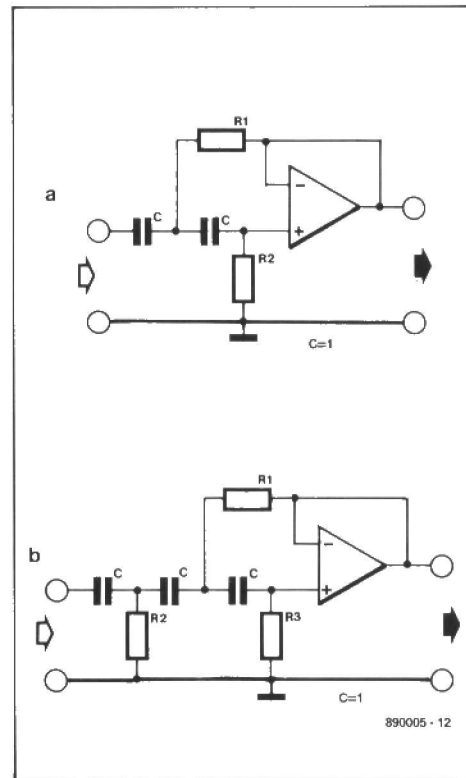


Fig. 20. Active high-pass sections with opamp connected as voltage follower: (a) two-pole type and (b) three-pole type.

where  $A$  is the amplification.

## Wide band-pass filters

In the computation of band-pass filters use may be made of a low-pass and a high-pass section that, dependent on the required characteristics — band-pass or band-stop — are connected in series or parallel respectively. This method can, however, only be used where the pass band or the stop band is wider than about an octave.

A schematic representation of a band-pass filter is given in Fig. 24. Here, a low-pass section and a high-pass section are connected in series, which results in only the common band ( $f_1$ — $f_2$ ) appearing at the output. The order in which the two are connected is not important as long as the low-pass cut-off frequency,  $f_2$ , is higher than that of the high-pass

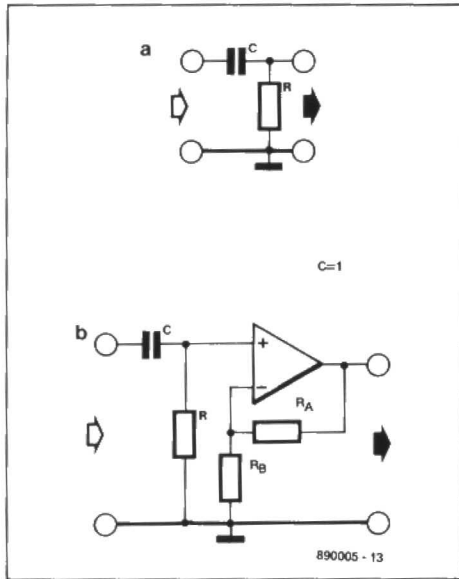


Fig. 21. A real pole is provided by a simple RC network (a). The addition of an opamp (b) enables buffering and amplification.

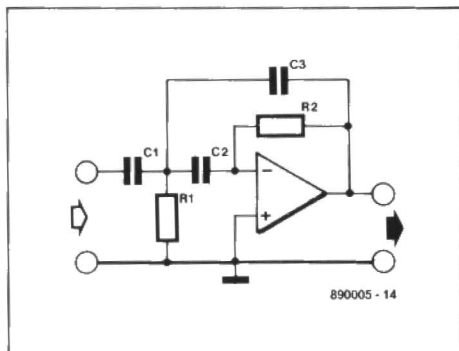


Fig. 22. A two-pole active high-pass section with variable gain.

section,  $f_1$ .

A schematic representation of a band-stop filter is shown in Fig. 25. Here, a low-pass section and a high-pass section are connected in parallel to prevent the band  $f_1$ — $f_2$  appearing at the output. The major difference between the filter in Fig. 24 and that in Fig. 25 is the fact that in the former the low-pass cut-off frequency is higher than the high-pass cut-off frequency, while in the latter it is the other way around.

The sections are computed in the usual way as discussed, after which they are combined. Both the band-pass and the band-stop filter may be passive or active. In a passive type the input and output impedances must be equal, otherwise there will be a mismatch that will adversely affect the filter characteristic. In the case of an active filter, the two sections are connected in cascade to form a band-pass filter, and in parallel with the aid of an additional summing amplifier to form a band-stop filter.

Next month's instalment will deal with narrow band-pass filters.

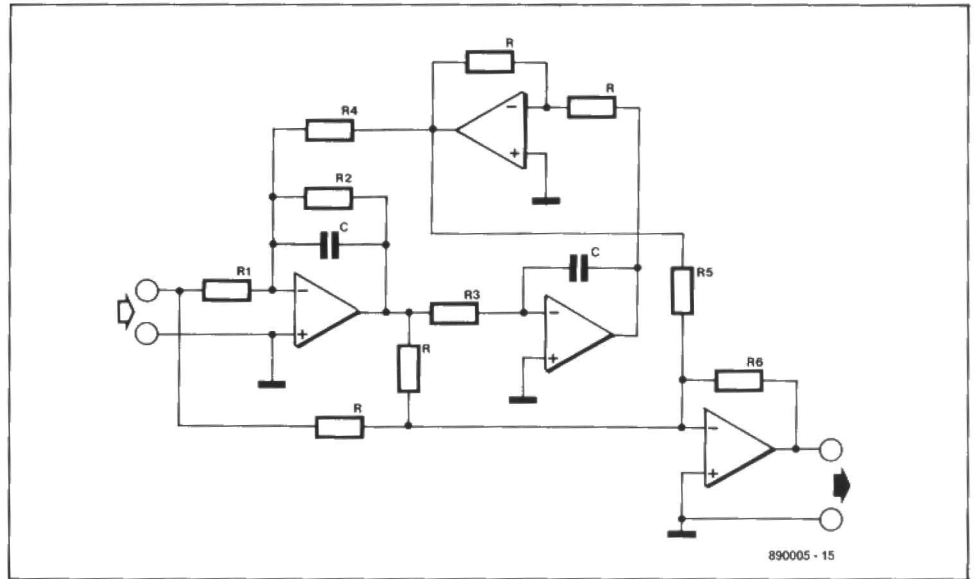


Fig. 23. A state-variable high-pass filter needs an extra opamp.

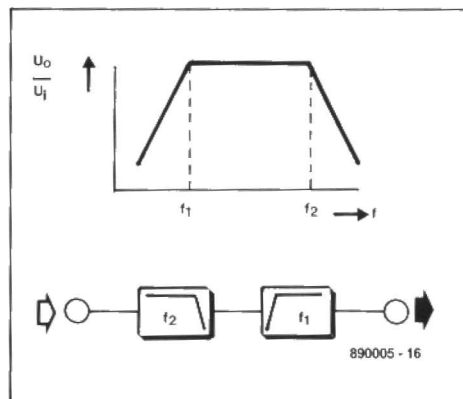


Fig. 24. A wide band-pass filter is obtained by connecting a low-pass section and a high-pass section in series.

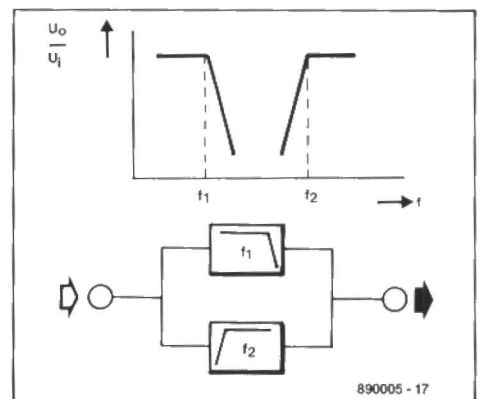
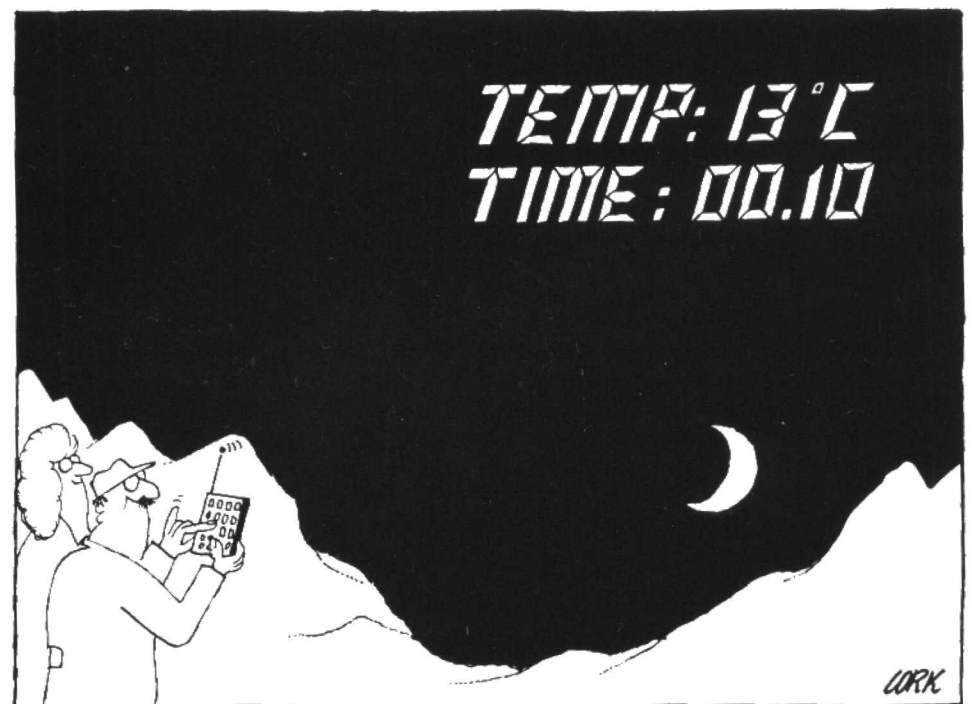


Fig. 25. A wide band-stop filter is obtained by connecting a low-pass section and a high-pass section in parallel.



## DESIGN IDEAS

The contents of this column are based solely on information supplied by the author and do not imply practical experience by *Elektor Electronics*.

# NEW CIRCUIT PROTECTION DEVICES FOR LOUDSPEAKER SYSTEMS

by Derek Overton\*

A novel type of circuit-protection device is now available to protect loudspeaker systems from damage.

Loudspeakers are generally designed and sold separately from amplifiers. Thus, mismatches may occur that can lead to damage. It should be noted that modern digital recordings often place additional burdens on an audio system.

Speaker damage may result from a number of factors, including the following.

- High-power amplifiers may simply overdrive the speech coils with excessive power on sustained programme material.
- Digital recordings, with their ability to reproduce high-frequency sound, place an extra strain on tweeters.
- Low-power amplifiers may be operated in clipping mode, which causes an upward frequency shift of power into the tweeter, resulting in an overload. This problem is especially common with the wide dynamic range of digitally programmed material.
- Unstable amplifier systems may oscillate in the ultrasonic range, which overloads the tweeter.

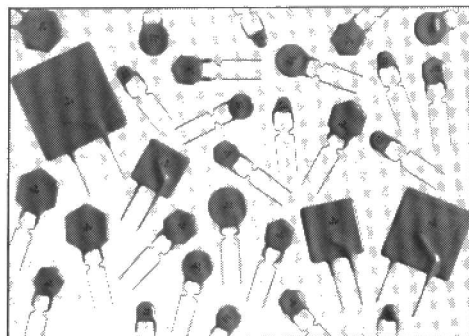


Fig. 1. A selection of Bourns MultiFuse™ resettable PTC circuit-protection devices.

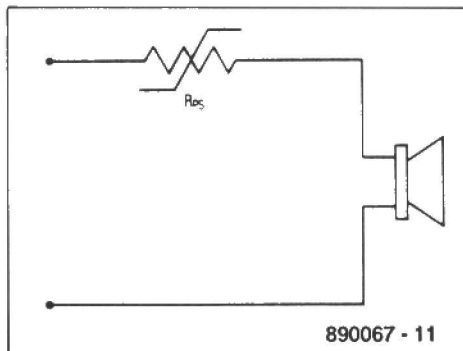


Fig. 2. A PTC device in a typical circuit.

A new range of Positive-Temperature-Coefficient (PTC) circuit-protection devices is now available to overcome these problems.

The new devices, known as MultiFuse™, act like fuses under overcurrent conditions, but "reset" themselves by returning to their low-resistance state once they cool below their "trip" temperature.

Because of this, they overcome the drawbacks of other overcurrent protection products such as fuse links, bimetallic circuit breakers or ceramic temperature-dependent resistors. Fuse links are not resettable; bimetallic circuit breakers are prone to vibration, welding, sparking, contact-resistance variation and recycling problems; and ceramic devices are slow in operation and may suffer from low-resistance or short-circuit problems under certain conditions.

Under normal conditions, the resistance of a MultiFuse™ device is comparable to that of a fuse link — between milliohms and a few ohms — depending

on the specified current-carrying capacity. When an overcurrent heats it up to its trip temperature, its resistance increases by many orders of magnitude, limiting the current from the power source and thereby protecting the circuit.

Once tripping has occurred, the residual current maintains the device above its trip temperature, and latches it in its protective high-resistance state. The device will return to its low-resistance state and reset once it cools below its trip temperature, which is achieved by switching the power off or substantially reducing the current. Once the fault condition has been cleared and the device reset, normal circuit operation resumes.

With a MultiFuse™ circuit protection device in series with a loudspeaker (either before or after the cross-over filter), a sustained overload causes the device to switch to a high-resistance state to protect the loudspeaker. A reduction in drive power, resulting either from a change in the music or by the user turning down the power, allows the device to reset automatically.

A properly sized device can be put in series with the loudspeaker to be protected as shown in Fig. 2. The device has a low resistance (typically 0.030-0.2 Ω for common loudspeaker sizes) and essentially no impedance.

Thus, the only effect on sound is a slight reduction in drive power (typically less than 0.1 dB). No measurable distortion has been found with normal signal levels.

A sustained overdrive condition causes the device to switch to high resistance. The speed of tripping depends on the amount of overcurrent. The resistance level in the tripped state (RPS) depends

\* The author is with Bourns Electronics Limited

on the power dissipation of the device (PD, which is essentially a constant) and the square of the drive voltage, V, specifically:

$$RPS \approx V^2/PD$$

Therefore, once a device trips, an increase in drive voltage raises, and a decrease lowers, the resistance of the device. The increased resistance is typically thirty to forty times higher than the base resistance, and this causes an abrupt reduction in power to the loudspeaker when the device trips.

The effect on load power is illustrated in Fig. 3. Initially, load power increases with drive voltage. When the drive voltage causes an excess current to trip the device, load power is reduced typically by 20-30 dB. Further increases in drive voltage reduce the load power even more.

A reduction in drive voltage increases the power to the load. Since the device is now the dominant load, it does not trace back the original curve. Rather, the drive voltage must be reduced until the device can no longer draw the power (typically 2-3 W) to maintain itself in the tripped state. The approximate condition for the device to untrip is:

$$V^2/4RL \leq PD$$

where RL is the load resistance. The untripping is visible on the decreasing drive-voltage portion of Fig. 3.

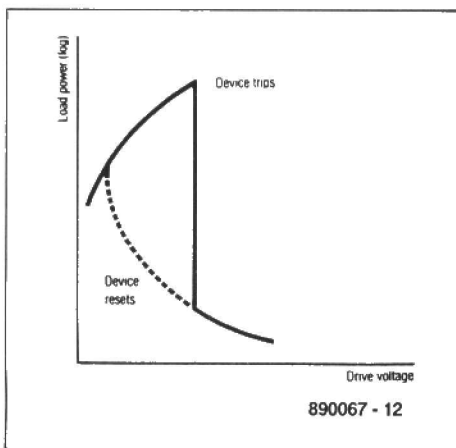


Fig. 3. Effect on load power.

Once the device has reset, normal operation is restored. Since the device has a somewhat higher resistance immediately after resetting, subsequent trips will occur at lower power during that period. If the user keeps the power down to obviate subsequent trips, the resistance relaxes and the component eventually resumes its initial value.

## Shunt resistance

Some users may like to reduce drive power by a known, fixed amount in the

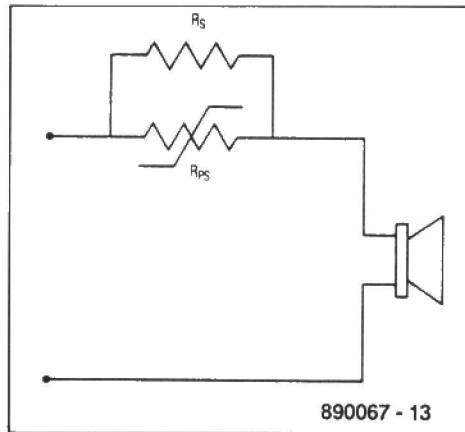


Fig. 4. PTC device with shunt resistor.

case of a fault, rather than the large variable amount provided by a MultiFuse™ device. Shunting the device with a fixed resistance as in Fig. 4 generates a fixed reduction if the device trips. The amount of reduction depends on the resistance used. The reduction in decibels is roughly

$$20\log[RL/(RL + RS)]$$

where RL is the load resistance and RS the shunt resistance.

Figure 5 shows the effects of a 5 Ω and a 10 Ω shunt resistance with a 1.85 A device. Until tripping occurs, the system follows the same curve as before (upper trace). When it trips, the device introduces an essentially fixed resistance in series with the load. This action reduces the output by a fixed amount. Now, the load power rises with increasing drive and diminishes with decreasing drive. The resistor must be rated to dissipate the power it would if the device were not in circuit.

In much the same way, a light bulb (typically an automotive bulb) can be connected in parallel with a MultiFuse™ device as shown in Fig. 6. Normally, the device carries by far the larger part of the current because its resistance will be less than one-fifth of that of the bulb.

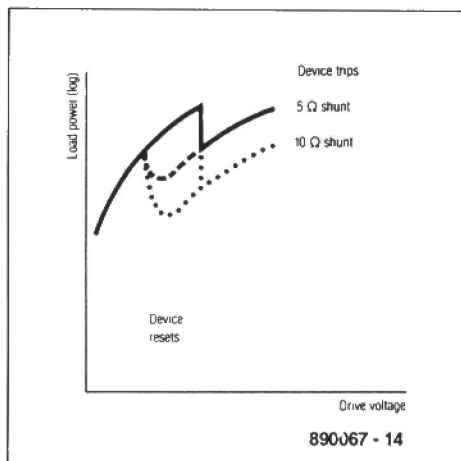


Fig. 5. Response of PTC device with shunt resistor.

When the device trips, most of the current flows through the bulb (which is also a PTC component). This introduces additional resistance into the circuit and limits the power. As with a fixed resistance, increases in drive voltage cause a rise in load power. However, owing to the variable PTC characteristic of the bulb (a resistance change of roughly 1:10 is available), that increase is less than proportional. As the drive power is reduced, the two PTC components go through a complex balancing act until the MultiFuse™ resets.

## Design considerations

The decision as to which MultiFuse™ to use must be based on a knowledge of the specific protection needs of the loudspeaker under design. An analysis of the

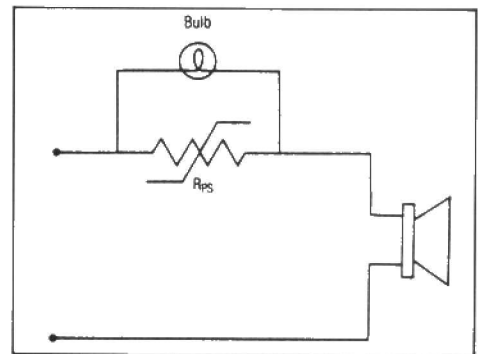


Fig. 6. PTC device with shunt light bulb.

time it takes to cause damage at various drive currents is very useful in understanding the protection needs of the driver. If this information is not available, an estimate of the maximum safe current can help. The amount of series resistance that can be added is also an important consideration. The data sheets for the MultiFuse™ devices show the minimum and maximum time-to-trip curves (normalized to I<sub>HOLD</sub>). If the designer has access to time-to-damage information for the driver, a comparison with the device's time-to-trip curves will indicate the part to try. If a complete time-to-damage curve is not available, the designer may choose a part with a current rating (I<sub>TRIP</sub>) just below the maximum safe current. In either case, the designer should conduct an empirical investigation to verify performance.

When carrying out such a study, the designer has to keep in mind that the longest time for a circuit device to trip is when it is new or has not been tripped for a long period. Therefore, the protection action of a device should be tested with fresh devices. On the other hand, the shortest time to trip occurs when the device has just tripped and the maximum normal operational conditions (current and temperature) therefore need to be tested with devices that have recently tripped.

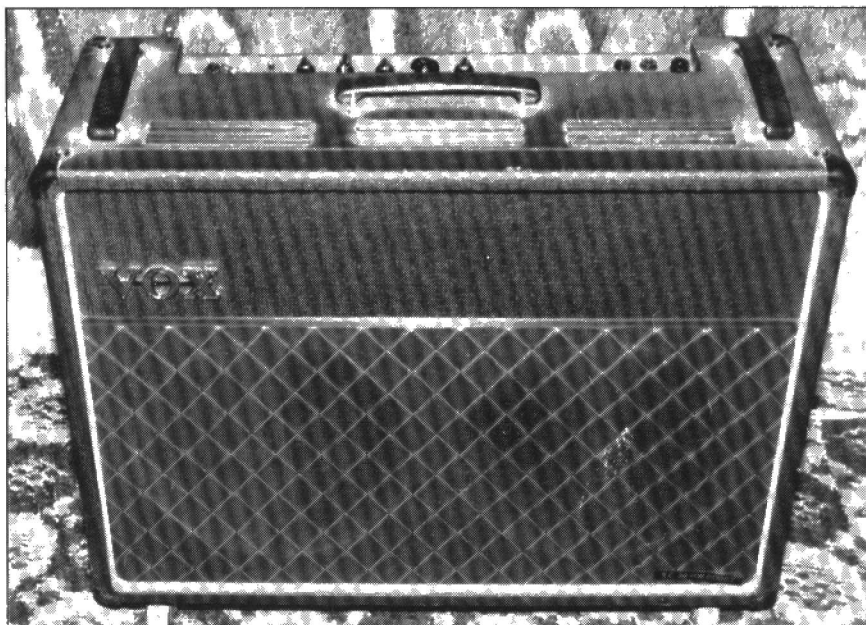
# UPGRADING THE VOX AC-30

by F.P. Zantis

To many players of the electric guitar, the Type AC-30 valved combo amplifier from VOX has a very special attraction, which is mostly due to its typical sound. This article describes how the now legendary AC-30 can be upgraded with features found on more up-to-date valve amplifiers.

The guitar amplifier, like the body of an acoustic guitar, boosts and modifies the otherwise very flat and weak sound of the strings. There are good grounds for the continued use, in a guitar amplifier, of valves instead of semiconductors. One of the reasons for this is that valves afford a dynamic range that is not so easily matched by a transistor circuit. To this comes the fact that the player has more difficulty controlling the final sound when there is a good deal of electronics in the signal path between the pick-up element on the guitar and the loudspeaker, as is the case with many solid-state amplifiers. Many players therefore prefer the relatively few electronic circuits of a valve amplifier to ensure that the full dynamic range and the original sound of the guitar are retained. The VOX AC-30 has these qualities, which, together with its instantly recognizable sound, makes it extremely popular even with the younger generation of guitar players. The amplifier is sometimes seen on stage alongside other, more modern types, and is typically used to give certain songs a particular quality. Some guitar players even use two AC-30s to achieve spatial stereo effects.

The AC-30 guitar amplifier was developed in the late thirties by the British company VOX. The basic concept of the electronics and the mechanical construction has remained unchanged for decades. The most fundamental technical point about the VOX AC-30 is the absence of any form of negative feedback. This has given rise to two typical qualities: first, the high overall



gain so achieved allows relatively few amplifier stages to be used ahead of the power stage, ensuring the previously mentioned original instrument quality; and second, the high, partly uncontrolled, gain results in a very distinct sound quality.

The designers of the original VOX AC-30 were probably not aware that the absence of feedback was to give the amplifier qualities not appreciated until long after the production of the amplifier had been discontinued. Very likely, feedback was not used simply because it had either not been fully developed yet for the particular application, or would have resulted in an amplifier that was too expensive.

## The circuit

The block diagram of the VOX AC-30 is given in Fig. 1. Three input channels are available, each with two input sockets. The amplifier may be connected to low- as well as high-impedance signal sources.

The 'normal' input allows driving the amplifier direct, i.e., without using an effects driver or tone control. The signal is amplified in a triode circuit and fed to the volume control. From there on, it goes direct to the phase splitter. With the exception of the four power valves, all active stages in the AC-30 are based on the high- $\mu$  twin triode Type ECC83.

The 'bright' input offers the highest voltage gain in combination with a tone control. The signal is amplified and filtered in 3 triode circuits before it is applied to the phase splitter.

The third input, marked 'Vib-Trem' enables the use of the vibrato and tremolo effects units inside the amplifier. These circuits are of relatively little importance, however, and will not be discussed further.

The power supply is simple and fairly up-to-date. The originally fitted double-phase rectifier with a grounded centre tap on the high-voltage secondary of the mains transformer has been replaced by a bridge rectifier. The taps on the primary of the mains transformer allow the amplifier to be used with different line voltages. The rectified plate voltage is smoothed by a  $47\ \Omega$  power resistor, a choke and a can-type electrolytic capacitor of  $2 \times 32\ \mu\text{F}$ . A separate winding on the power transformer provides the filament voltage. The 30 W power output stage is a conventional class-A push-pull design with two parallel EL84s for each phase.

## Tips and tricks

Changing the sound quality of the VOX AC-30 is, to many, sacrilege. Guitar

players not satisfied with the basic sound of the VOX AC-30 had, therefore, best look for a different amplifier altogether. There are, however, two possible enhancements to the amplifier, and these have to do with reliability and ease of use.

One of the disadvantages of the class-A power output stage in the AC-30 is that the Type EL84 tetrodes are continuously operated near their maximum specification as regards permissible dissipation. A defective output valve readily causes the  $47\ \Omega$  series resistor and/or one or more rectifier diodes in the supply to burn out. In accordance with Murphy's laws, this will always happen just before or during a 'live' performance. One way of avoiding such situations is to measure the loaded plate voltage available when the amplifier is set to the next higher mains voltage. In many cases, this setting is altogether safer, and avoids overloading the power valves at the cost of a small reduction in output power. The rectifier diodes may also be replaced by types with a higher permissible forward current, e.g., BY133. Since the  $47\ \Omega$  series resistor functions as a fuse, it may only be replaced with a 5 W type if the amplifier is immediately switched off when any malfunction is noted. After locating and removing the defective valve, two or all four EL84s should be replaced to ensure correct gain distribution. When no spare valves are available, the VOX AC-30 may be used with only one pair of output valves fitted. The missing valves should, however, be installed as soon as available.

One obvious shortcoming of the VOX AC-30 is the absence of a master volume control which may, however, be installed as an upgrade.

A 1 M $\Omega$  stereo potentiometer is inserted in the signal path between the phase splitter and the power stage as shown in Fig. 2. Two further parts needed for this modification are 150 nF; 400 V capacitors that block the high direct voltage. The potentiometer, which is connected with the aid of screened wires, allows the preamplifier stages in the AC-30 to be overdriven by almost any type of pick-up device. The degree of (controlled) distortion so introduced depends mainly on the way the guitar is played. Also shown in Fig. 2 is an option for volume control by foot-switch, which is particularly useful for solos. The foot-switch controls a relay, which, in the actuated state, opens its contacts and effectively inserts 100 k $\Omega$  resistors in the ground paths of the master volume potentiometers. This results in a higher volume. Although the difference between solo and rhythm volume decreases with higher settings of the basic volume, the effect is still very useful in practice because most players will leave the basic

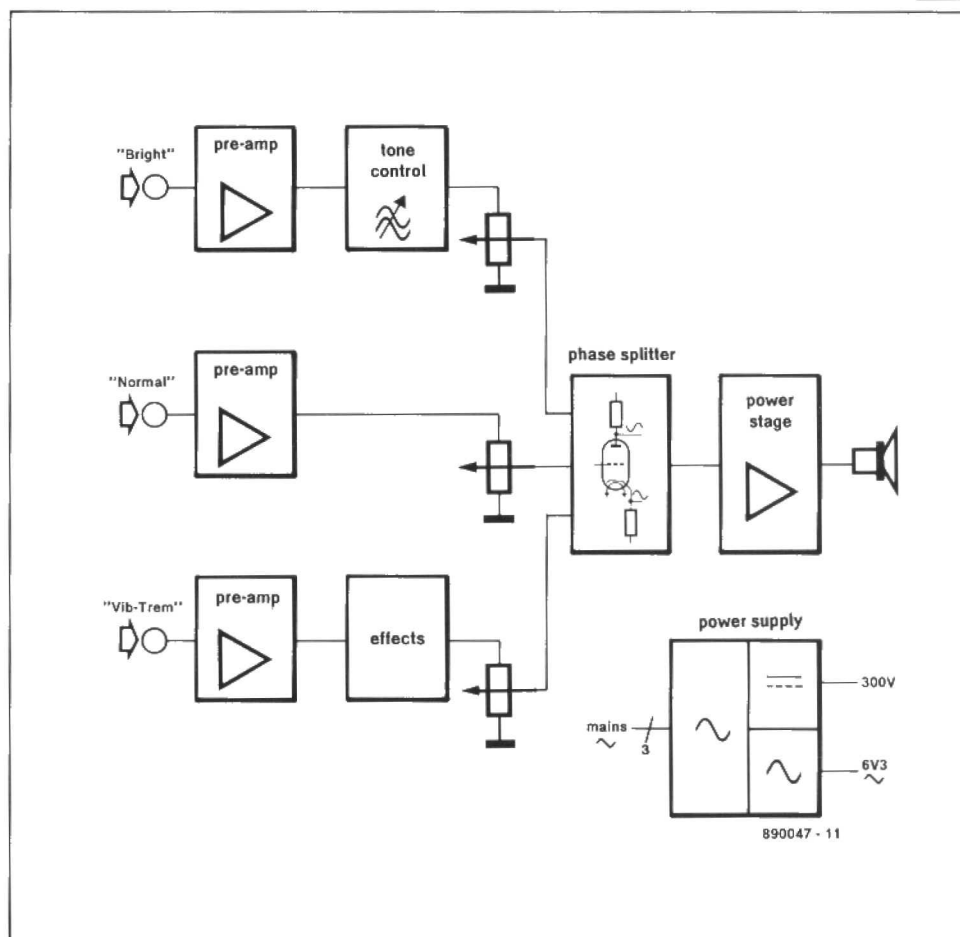


Fig. 1. Block diagram of the VOX AC-30 guitar amplifier.

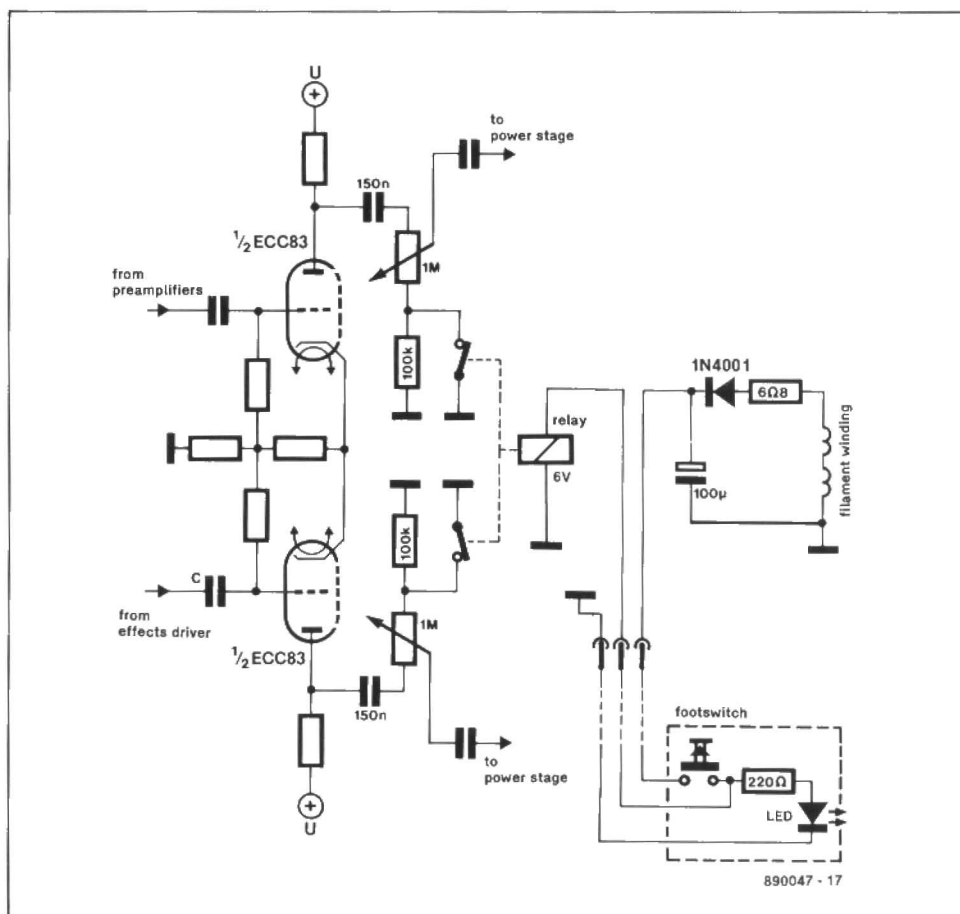


Fig. 2. Modified phase splitter stage with master volume control and foot-switch controlled solo/rhythm control.

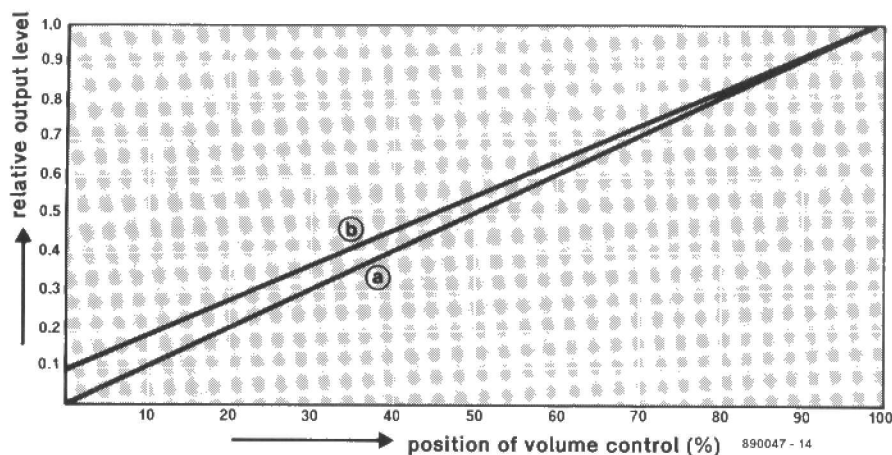


Fig. 3. Relative amplifier output level as a function of the master volume setting with the solo switch off (a) and on (b).

volume setting unchanged during most of the performance. The curves in Fig. 3 show the relative volume response of the amplifier with the solo switch on (curve a) and off (curve b). Since the switch-over is effected at the master volume control, the basic sound of the amplifier is not affected. The relay is powered from the filament winding on the mains transformer.

The VOX AC-30, like many older combo amplifiers, lacks a stand-by switch. Figure 4 shows how this can be post-installed in series with the 47  $\Omega$  resistor in the power supply. Apart from the obvious advantage of extending valve life, the switch enables the amplifier to be muted while connecting other instruments or cables.

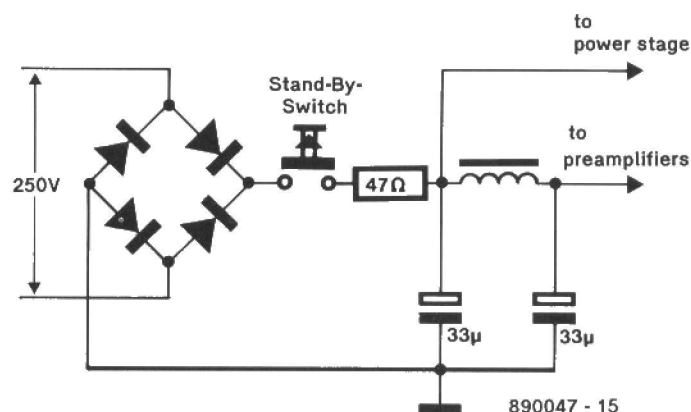


Fig. 4. Stand-by switch in the HV power supply.

## In practice

The proposed modifications to the VOX AC-30 are illustrated in a number of photographs that show further practical suggestions.

The effects circuits in the author's amplifier were removed to make place for modifications and extensions. The removal requires the free side of capacitor C (Fig. 2) to be connected to ground. The original low-impedance termination at the 'bright' input was modified as shown in Fig. 5 to achieve higher sensitivity. The front panel of the amplifier was fitted with the master volume control and a socket for the remote foot-switch. Since the socket used was a non-insulated type, the hum suppression preset across the filament winding had to be removed. One side of the filament winding is connected to ground as shown in Fig. 2. Fortunately, this modification did not noticeably increase the hum level. The LED inside the foot-switch indicates solo or rhythm selection.

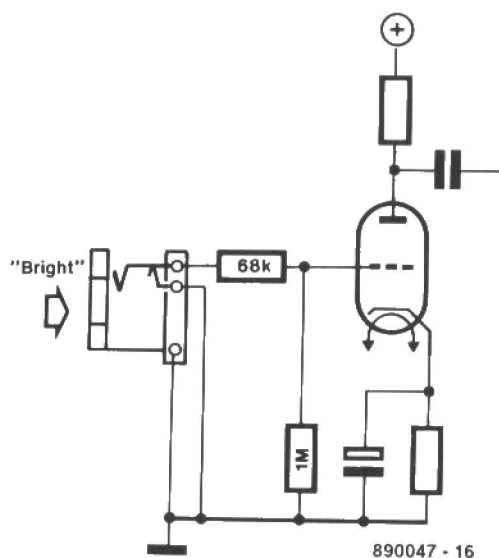


Fig. 5. Modified 'bright' input circuit.

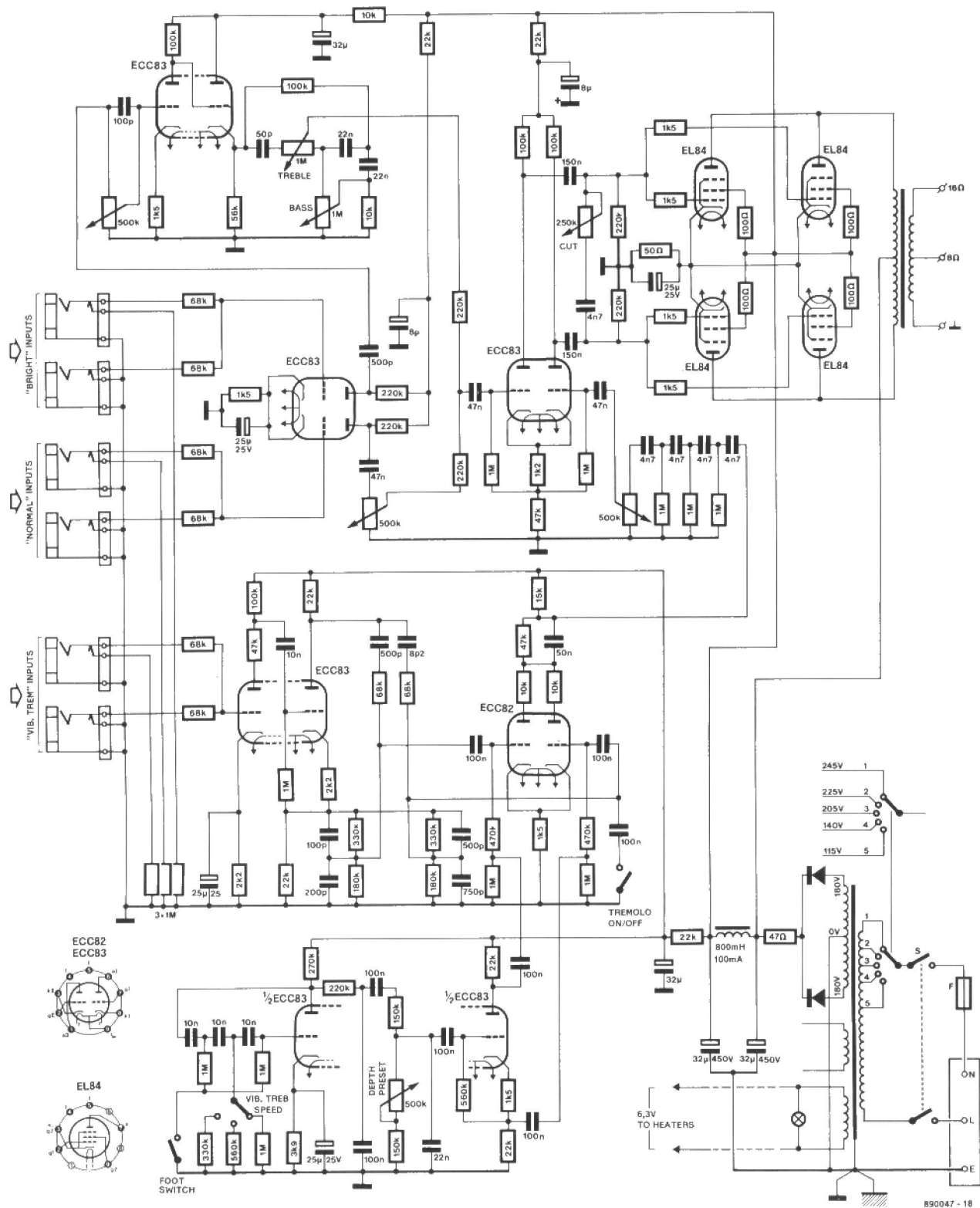


Fig. 9. Complete circuit diagram of the VOX AC-30 before the modifications.

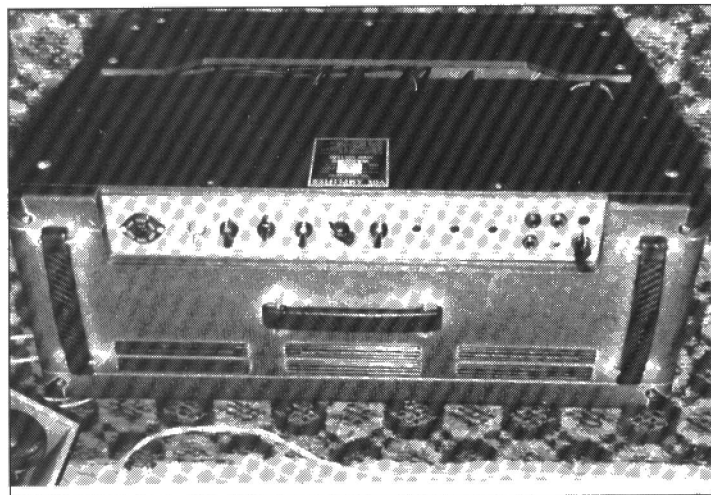


Fig. 6. Modified control panel of the author's VOX AC-30 with master volume control and foot-switch input socket.

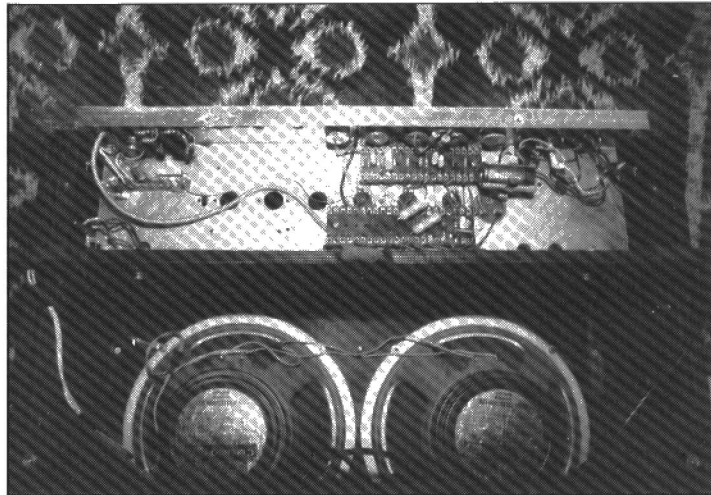


Fig. 7b. Rear interior view of the modified amplifier. The 150 nF capacitors on the lower tag strip are required for the add-on master volume control.

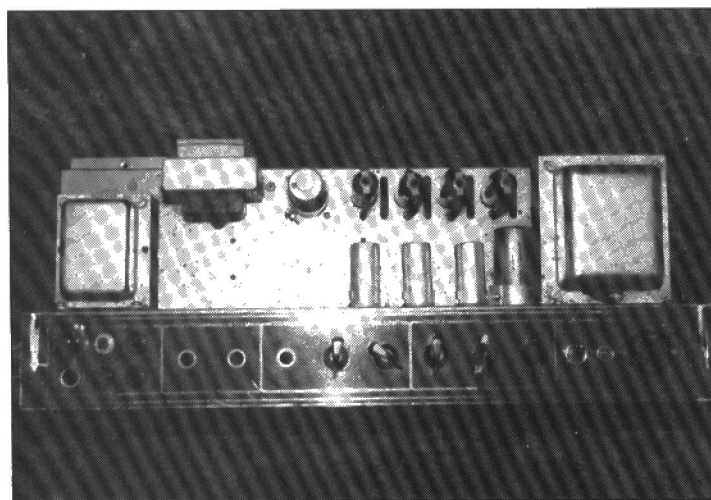


Fig. 7a. Top view of the chassis with all effects circuitry removed. The three remaining twin triodes are covered in spring-loaded shielding hoods. The left-hand valve is part of the preamplifier, the centre valve is the phase splitter, and the right-hand valve functions in the tone control circuit. The four output valves are seen above the triodes.

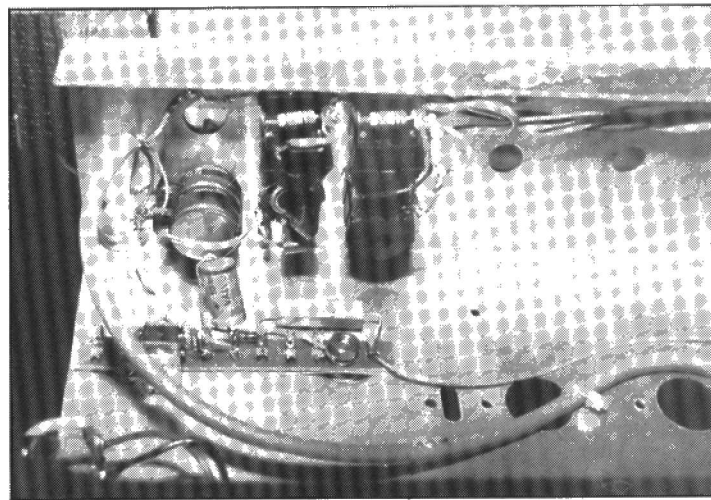


Fig. 8. The foot-switch controlled volume selection circuit for solo playing is mounted on a tag strip below the input sockets. The ganged master volume potentiometer and the foot-switch socket are seen at the top.

## CORRECTIONS

### AM/FM VHF receiver

February 1989, p. 51 - 55.

The constructional descriptions of inductors L5 and L6 have been transposed in the text on page 53 under *Building the receiver*. The correct descriptions are as follows:

L5 = VHF choke; 4 turns of 0.2 mm dia. enamelled copper wire, wound through a 3 mm long ferrite bead.  
L6 = 8 closewound turns of 0.2 mm dia. enamelled copper wire; internal diameter of the inductor is about 3 mm, and no former is used.

### Colour test-pattern generator

December 1988, p. 50 - 55.

On the printed-circuit board for this project, Type

EPS-880130, pins 7 and 10 of IC21 (FF3) should be connected to +5 V.

### MIDI control unit Q4

January 1989, p. 20 - 27.

Mains transformer Tr1 has a power rating of 500 mA, not 1500 mA as shown in the circuit diagram of Fig. 2.

The following text replaces the final paragraph of the section *Programming example* (page 24; left-hand column, below the datastring):

Value pp is the preset to be programmed, dd a 32-byte string in which bytes 1 to 21 correspond to the parameters of the relevant preset, and bytes 22 to 32 are zeros. String 48 45 4E 52 49 stands for 'HENRI'. Similar to the above loading procedure, a preset can be read back from the Q4 by sending

F0 48 45 4E 52 49 02 pp F7

where pp is the preset to be read. The Q4 answers with a string in which 'HENRI' has been changed to 'hENRI'. This is done to avoid confusion with a possible local echo on the computer. The returned string has the following structure:

F0 38 45 4E 52 49 02 pp dd . . . dd F7

where pp is the number of the relevant preset, and dd the associated 32-byte parameter string, in which the first 21 bytes are data, and the remaining 11 are all 0.

### MOSFET Hi-Fi POWER AMPLIFIER

February 1989, p. 14 - 18.

The PCB overlay shown in Fig. 3 is incorrect for the 60 or 80 W version of the amplifier: the base and emitter terminals of TO-92 style transistors T12 and T13 should be fitted the other way around from shown.

# MULTI-POINT INFRA-RED REMOTE CONTROL

by T. Giffard

Much of today's audiovisual equipment is remote-controlled from a handheld infra-red transmitter. The multi-point control system described here extends the range of these systems, so that, say, a VCR installed in the living room can be controlled from the bedroom, or, when more than one receiver is used, from any place in the home where a 'local IR feedpoint' is installed.

There is little point in using high-power infra-red emitter devices for extending the range of an IR-based remote control for audiovisual equipment in the home, simply because an infra-red beam travels by line of sight, and can not pass through a wall. None the less, the usable range may be increased by interconnecting a number of 'local' IR receivers in a network whose output drives a central transmitter pointed at VCR, TV or audio equipment. In this manner, the IR signal from one or more transmitters used at some distance from the equipment is picked up locally and relayed to the central control.

One example of the use of the multi-point IR remote control concerns a combination of a CD player and an audio amplifier that drives a remote pair of loudspeakers. An IR receiver is installed in the 'remote' room, and connected to the central control in the living room via a length of coax cable. The IR trans-

mitter that 'belongs to' the audio rack can then be used for volume control and even programme selection in the room with the extra pair of loudspeakers. As already stated, the system allows several locally fitted IR receivers to be interconnected via a single coax cable.

The block diagram of the proposed system is given in Fig. 1. The receiver picks up the signals from the IR remote control transmitter. The photon current generated in an IR photodiode at the input of the receiver is converted to a voltage that is subsequently amplified and filtered. A double T-filter is used to suppress modulated 100 Hz hum on incident light from fluorescent tubes and other light sources.

A comparator/buffer at the output of the receiver feeds the remote control signal into the coax cable to the transmitter, which is a simple power output stage driving three infra-red emitter diodes (IREDs). The transmitter is fitted

at a point within the normal reach of the receiver that forms part of the audio or audiovisual equipment.

## Practical circuit

The circuit diagram in Fig. 2a shows that the photodiode, a BP104, is connected to the inverting input of current-to-voltage (I-V) converting opamp IC<sub>1</sub> via a coupling capacitor, C<sub>2</sub>. The capacitor prevents slow changes in the ambient light intensity being passed to the opamp. The photodiode is reverse-biased by decoupled series network R<sub>1</sub>-R<sub>2</sub>. This is done to reduce the parasitic capacitance in the off-state of the photodiode, and thereby ensure a short pulse response time. Since the receiver is a single-supply design, the non-inverting input of IC<sub>1</sub> is held at half the supply voltage with the aid of potential divider R<sub>4</sub>-R<sub>5</sub>.

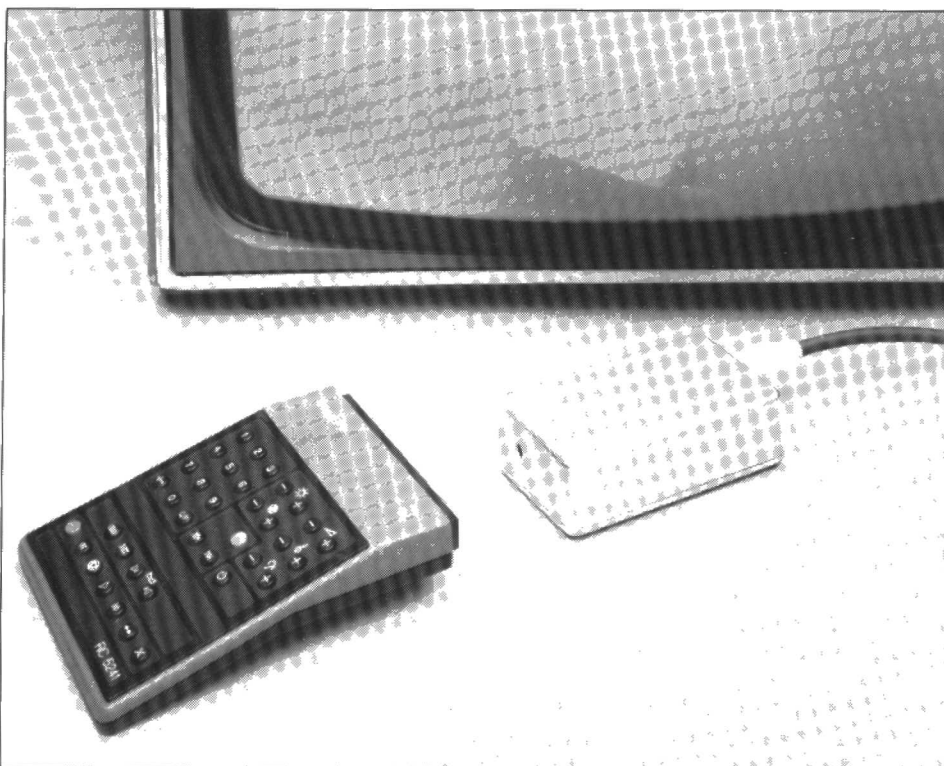
The amplified voltage at the output of the I-V converter is applied to a double T-filter, R<sub>6</sub> through R<sub>9</sub> and C<sub>3</sub> through C<sub>8</sub>, dimensioned for 100 Hz. The filter has no effect on the pulse train received from the IR transmitter, because this signal usually has a frequency much higher than 100 Hz.

A buffer/comparator stage built around another fast opamp, IC<sub>2</sub>, restores the shape of the control pulses and drives output stage T<sub>1</sub>-T<sub>2</sub>. In this stage, T<sub>2</sub> functions as a 200 mA current source, so that the termination impedance of the coax cable is determined by R<sub>14</sub> only. The current source also prevents problems arising from the parallel connection of several receivers to the single coax cable.

The pulses at the output of IC<sub>2</sub> switch T<sub>1</sub>, which in turn switches the current source, T<sub>2</sub>, on and off.

Preset P<sub>1</sub> compensates the off-set introduced by both opamps. The adjustment of this compensation will be reverted to in detail because it is essential for correct operation of the control system.

The receiver is powered by a small mains adapter providing 12 VDC output at about 250 mA. The use of a mains



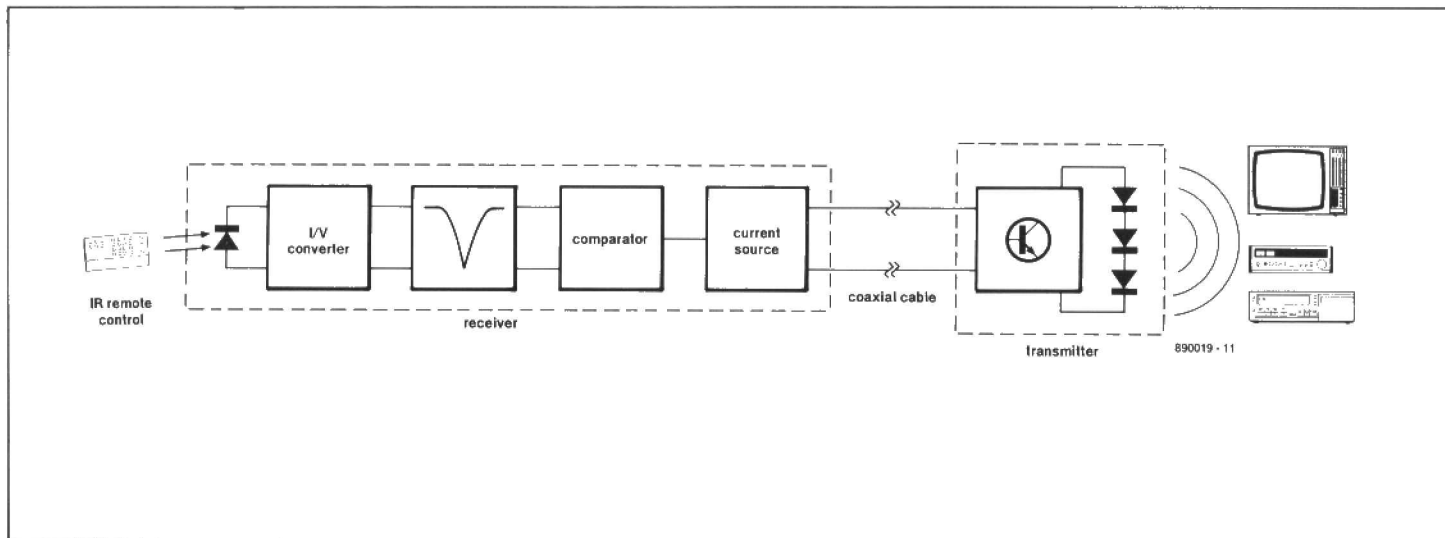


Fig. 1. Block diagram of the multipoint IR remote control system.

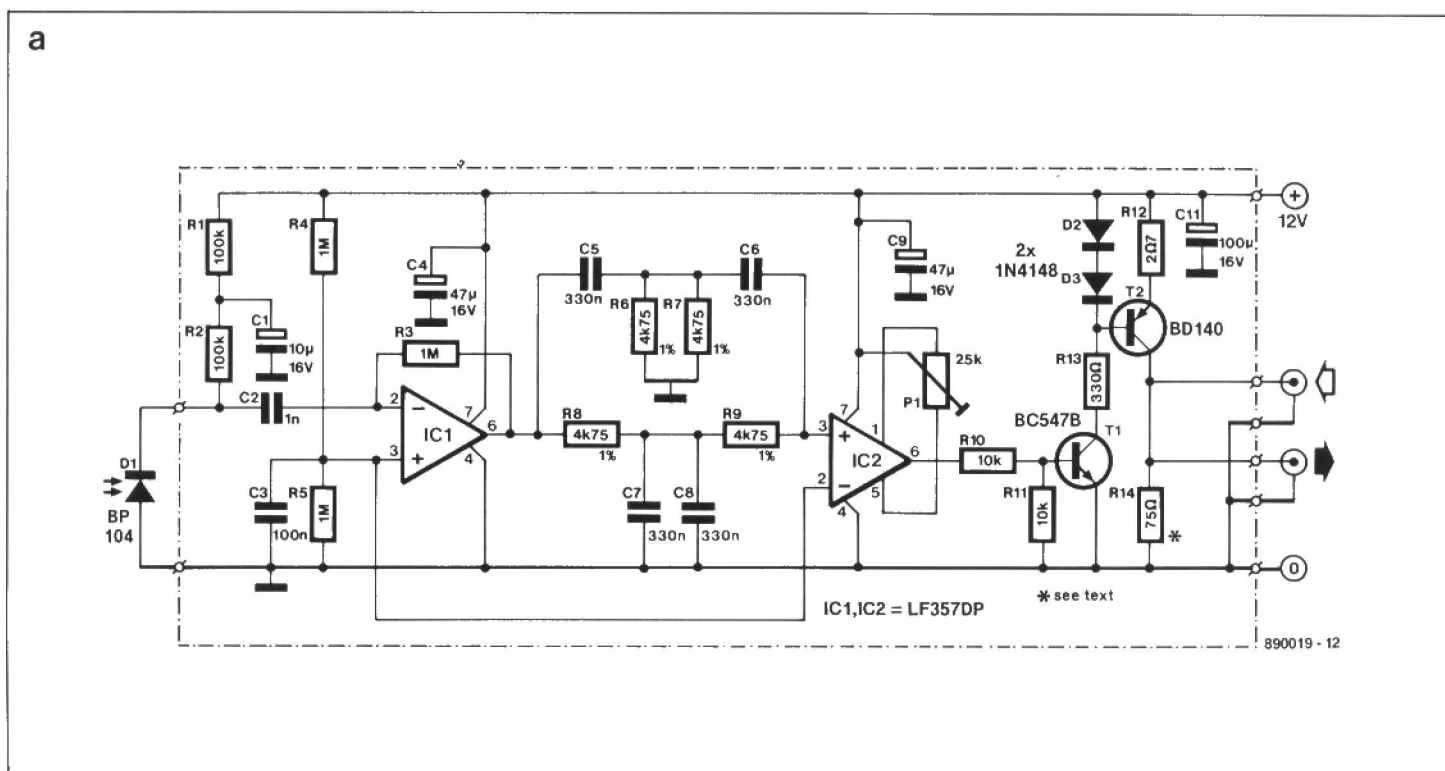


Fig. 2. Circuit diagram of the receiver (a) and transmitter (b).

power supply in the same enclosure as the IR receiver is not recommended for reasons of safety and possible interference.

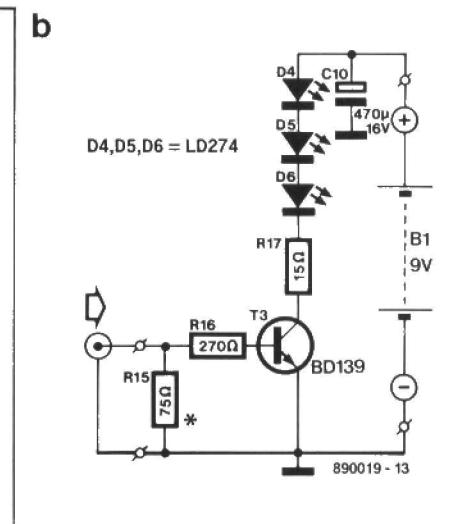
The central IR transmitter (Fig. 2b) is essentially composed of a medium-power transistor,  $T_3$ , and 3 series-connected IREDs fitted with small reflectors. By virtue of the current source(s) in the receiver(s), the IRED driver can be powered from a 9 V battery because it only draws current when a pulse is transmitted.

### Construction

The multi-point IR remote control system is simple to build on the printed circuit boards shown in Figs. 3 (receiver)

and 4 (transmitter). For optimum noise suppression, the completed receiver board is either screened with tin or brass plates, or mounted in a metal enclosure with holes for the supply cable, the coax cable(s) and, of course, the photodiode. The latter should remain on the PCB, i.e., it must not be connected with a cable, however short this may be. When several receivers are connected to the coax cable, *only the one at the end of the cable* should be fitted with a 75  $\Omega$  termination resistor,  $R_{14}$ . Each receiver is best mounted near a mains outlet, at a height of about 1 m above the floor.

The transmitter plus battery may be mounted in an ABS enclosure, which is permanently installed in the same room



as the controlled equipment. The IREDs must, of course, be pointed towards the receiver diode in the equipment.

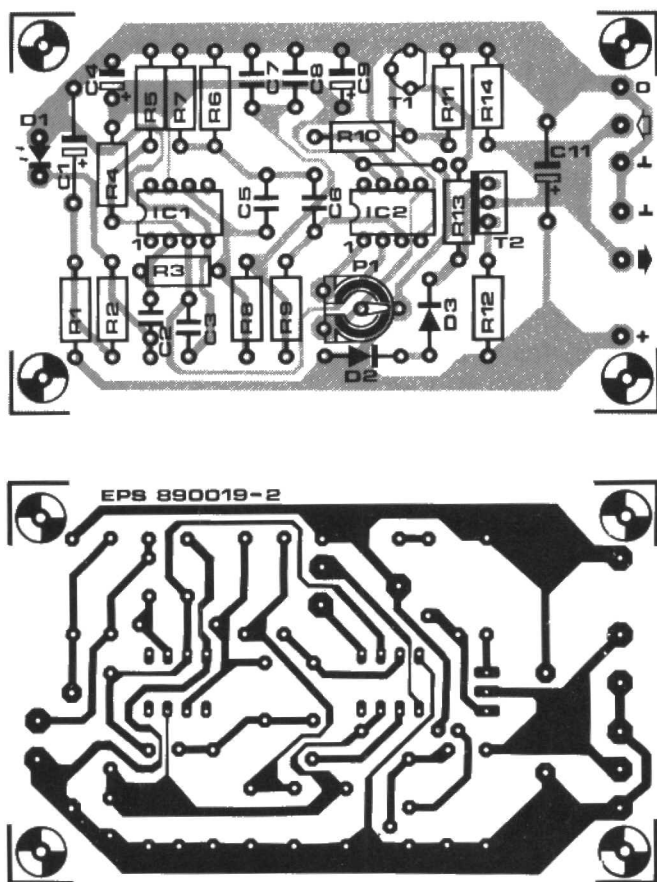


Fig. 3. Printed-circuit board for the IR receiver. Screening is essential!

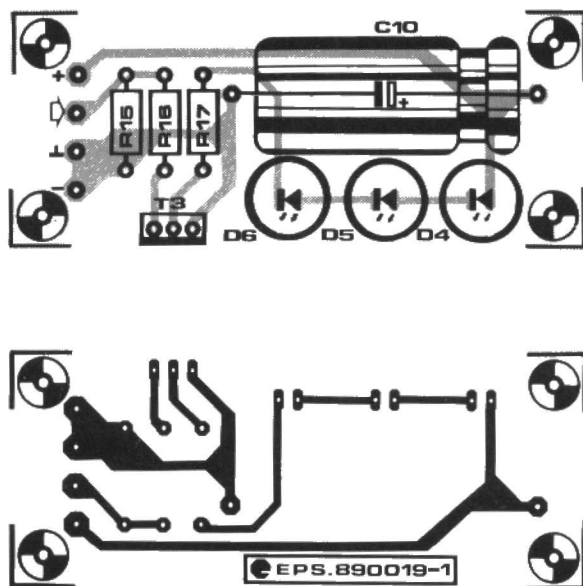



Fig. 4. Printed-circuit board for the IR transmitter.

### Setting up

Preset P<sub>1</sub> should be adjusted with care to avoid the transmitter draining the battery in a few minutes, or R<sub>17</sub> overheating.

Disconnect the transmitter from the receiver(s). Apply power to the receiver, and connect a DC voltmeter to the output of IC<sub>2</sub> (pin 6). Carefully adjust P<sub>1</sub> until the output is just low when no

signal is received. If available, an oscilloscope may be used to verify the absence of oscillation signals or interference at the output. The transmitter is then connected again, and the multi-point IR control is ready for use. 

### Parts list

#### INFRA-RED RECEIVER:

##### Resistors ( $\pm 5\%$ ):

R<sub>1</sub>; R<sub>2</sub> = 100K  
 R<sub>3</sub>; R<sub>4</sub>; R<sub>5</sub> = 1M0  
 R<sub>6</sub>... R<sub>9</sub> incl. = 4K75; 1%  
 R<sub>10</sub>; R<sub>11</sub> = 10K  
 R<sub>12</sub> = 2R7  
 R<sub>13</sub> = 330R  
 R<sub>14</sub> = 75R (see text)  
 P<sub>1</sub> = 25K preset H

##### Capacitors:

C<sub>1</sub> = 10 $\mu$ ; 16 V  
 C<sub>2</sub> = 1n0  
 C<sub>3</sub> = 100n  
 C<sub>4</sub>; C<sub>9</sub> = 47 $\mu$ ; 16 V; tantalum  
 C<sub>5</sub>... C<sub>8</sub> incl. = 330n  
 C<sub>11</sub> = 100 $\mu$ ; 16 V

##### Semiconductors:

D<sub>1</sub> = BP104  
 D<sub>2</sub>; D<sub>3</sub> = 1N4148  
 IC<sub>1</sub>; IC<sub>2</sub> = LF357DP  
 T<sub>1</sub> = BC547B  
 T<sub>2</sub> = BD140

##### Miscellaneous:

PCB Type 890019-1 (see Readers Services page).  
 Mains adaptor 12 VDC @ 250 mA.

### Parts list

#### INFRA-RED TRANSMITTER:

##### Resistors ( $\pm 5\%$ ):

R<sub>15</sub> = 75R  
 R<sub>16</sub> = 270R  
 R<sub>17</sub> = 15R

##### Capacitor:

C<sub>10</sub> = 470 $\mu$ ; 16 V

##### Semiconductors:

D<sub>4</sub>; D<sub>5</sub>; D<sub>6</sub> = LD274  
 T<sub>3</sub> = BD139

##### Miscellaneous:

PP3 9 V battery.  
 3 reflectors (for D<sub>4</sub>, D<sub>5</sub> and D<sub>6</sub>).  
 PCB 890019-2 (see Readers Services page).

# TRIPLET: AN 80-W HI-FI LOUDSPEAKER SYSTEM

by H. Baggott

**Based on SEAS drive units, the satellite-subwoofer combination described here offers a high-quality system that has a straight frequency characteristic ( $\pm 3$  dB) from 30 Hz to 20 kHz and can handle powers up to 80 watts.**

Although it is well known that the quality of reproduction of an audio system depends primarily on the quality of the loudspeaker system, it remains a fact that most buyers of an audio system who have to have watch the outlay invariably economize first on the loudspeaker system. Apart from cost, the other reason that people buy too small loudspeakers is lack of space in the living room. It is, after all, a fact that a good loudspeaker system is housed in a pair of fairly large enclosures. Or is it?

The TRIPLET system uses one large enclosure that houses the subwoofers and two much smaller (satellite) boxes that house the mid-frequency and tweeter units. The subwoofer box may be placed almost anywhere in the room because low-frequency signals are virtually non-directional. The satellite boxes may conveniently be placed in, say, a book case amidst some books.

The three-box loudspeaker system has also drawn the attention of a number of commercial manufacturers and there are, therefore, several such systems on the market. They are, however, not cheap: prices range from about £400 to around £800. The TRIPLET system may be built for about £300 (£250-£270 for the drive units and £30-£40 for the materials for the boxes).

## Choice of drive units

The Norwegian firm of SEAS is well known for its excellent drive units that are used in many high-quality systems. It is also one of the very few whose catalogue includes a low-frequency unit that is suitable for the present system. The LF drive unit has to be something special. Since the woofer enclosure houses two LF units, even at low frequencies fairly high sound pressures are produced.

The LF unit chosen is the Type CA21 REX4X/Dc, which is a 21-cm type constructed on a cast magnesium chassis that has a double voice coil and a coated paper cone. In spite of that double speech coil, one unit is used for each

channel. This may seem odd, but for this application a unit is needed with a high moving mass and the double coil provides a few extra grammes. Furthermore, the sensitivity of the TRIPLET is somewhat on the low side and this is compensated to some extent by the use of a highly efficient LF unit. With the two speech coils connected in parallel, the sensitivity of the LF unit is some 90 dB and this helps to raise the system sensitivity to an acceptable figure of 84 dB (1 W/1 m).

The mid-frequency unit in each satellite is an 11-cm Type 11 F-GX. This unit also has a cast chassis and a coated paper

without the resonance peak so typical of most soft-dome tweeter units.

## Design considerations

The aim of the design was to construct a system with very small satellite enclosures (volume of around 1.5 litre) and a subwoofer that would faithfully reproduce very low frequencies. The finished satellite boxes are 220×120×120 mm (H×W×D); the net internal volume is just about 1.5 litre. This is just right to ensure a low cut-off frequency of 150 Hz at a  $Q_{TC}$  of 0.6.

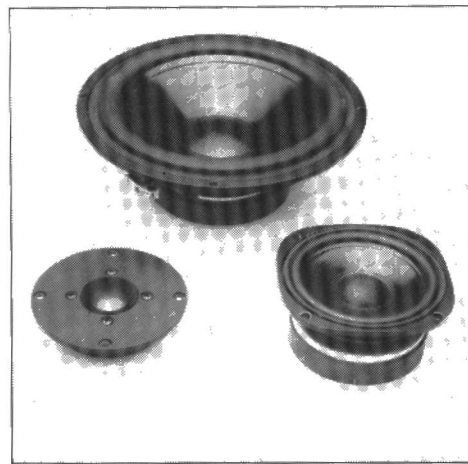
The subwoofer is housed in a twin enclosure of total internal volume of 65 litres. Its frequency range extends from 30 Hz to 150 Hz ( $\pm 3$  dB). At first sight, the low cut-off point is not so impressive, but do bear in mind that most box manufacturers quote the low cut-off point not at  $-3$  dB, but normally at  $-6$  dB or even  $-10$  dB: that makes quite a difference!

## The subwoofer principle

The principle of a subwoofer system is shown in Fig. 2. The drive unit is loaded at the back by a closed chamber and at the front by a vented chamber, that is, one having an open tunnel or port. Such a vented chamber is comparable to a 24 dB/octave cut-off high-pass filter, and is, therefore, often called an acoustic filter.

Figure 3 shows what happens in this twin-chamber system. The solid curve is the frequency characteristic of the drive unit in the closed chamber. The dotted curve is the frequency characteristic of the vented chamber. The sum of these characteristics is a band-pass curve with a flat centre section (shown by dashed line).

Since the resonance frequency of the acoustic filter is lower than the cut-off point of the closed chamber, the resulting overall cut-off frequency of the two-chamber system is much lower than either of these two. It is thus possible to reproduce very low frequencies ef-



**Fig. 1. The three SEAS drive units used in the Triplet system.**

cone. It is one of the very few mid-frequency units on the market with a resonance frequency low enough to allow its use in a closed box down to 150 Hz. Its construction also allows fairly large deflections without introducing distortion. The dimensions of the magnet this unit uses are eye-catching. It is not an inexpensive unit, but both acoustically and mechanically it is excellent.

The tweeter units are 25-mm aluminium dome Types H 398. A noteworthy characteristic of this unit is the slow and smooth frequency fall-off above 20 kHz

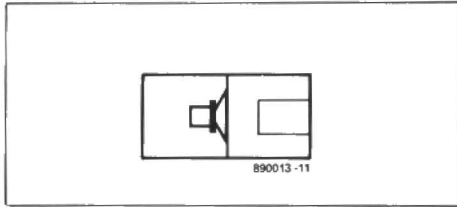


Fig. 2. The principle of operation of a subwoofer: the drive unit is located between a closed chamber and a vented one.

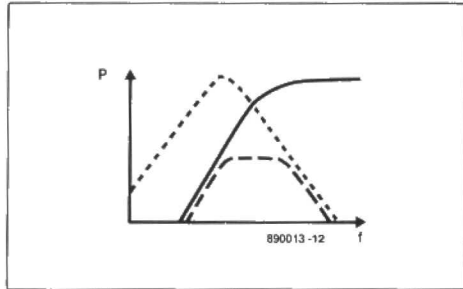


Fig. 3. The vented chamber, often called an acoustic filter, passes a portion of the frequency response provided by the closed chamber.

ficiently with a relatively small-volume enclosure.

Since the drive unit is loaded both at the front and at the back, it will not easily be damaged. No poor load capacity below the resonance frequency as is the case in a bas reflex (vented) enclosure.

Another advantage of the subwoofer system is the inherent frequency characteristic which makes it possible for the electrical filter to be kept relatively simple.

The system also has a drawback: the sensitivity is fairly low because the acoustic filter passes part of the slope of the characteristic of the original closed box. The two-chamber system gives a fair degree of freedom in the design. It is, for instance, possible to extend the frequency range downward by lowering the cut-off point of the closed chamber, but this will be at the expense of sensitivity. The Q factor of the closed chamber is also important, since it determines the slope of the leading edge of the frequency characteristic. To obtain a level centre section of the characteristic, it is necessary for the leading edge of the

characteristic to have the same slope as the trailing edge.

Furthermore, the upper cut-off frequency must match the lower cut-off point of the satellites.

In short, there are a number of possibilities, but this makes random experimenting a sure way to disaster.

In the present design two two-chamber systems have been combined in one enclosure as shown in Fig. 4. By combining the two vented chambers, the result is a three-chamber box. The use of two low-frequency drive units enables fairly high sound pressures to be achieved even at very low frequencies, something that quickly leads to problems if only one drive unit is used.

The closed chambers each have a net volume of 22 litres, while the composite vented chamber is about 21 litres, to give a net total enclosure volume of 65 litres. It is virtually impossible to construct a closed box or a bas reflex enclosure with a volume of 65 l that has a -3 dB cut-off point at 30 Hz.

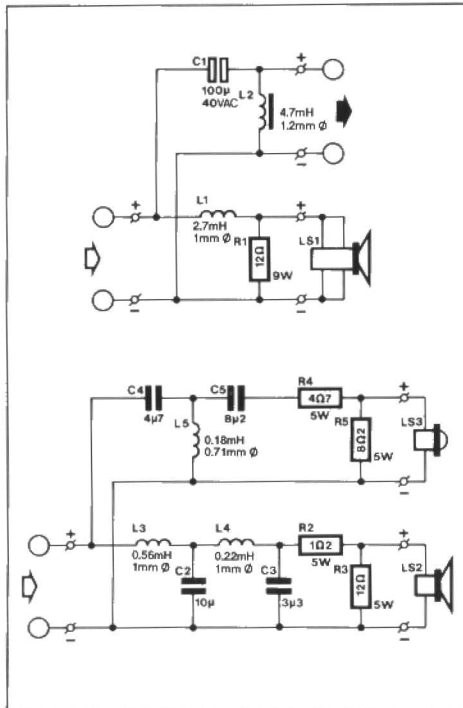


Fig. 5. The circuit diagrams of the cross-over filters for the subwoofer (a) and for the satellite (b).

The length of the tunnel (vent, port) is very important: in the present design it is 24 cm. Only a few centimetres deviation from this results in a changed frequency characteristic and lowered efficiency. None the less, the shape of the overall enclosure may be altered as desired, as long as the volumes of the three chambers and the length (and diameter) of the vent are as stated.

### The cross-over filter

The cross-over network has been designed with the aid of a computer program that takes account of the ampli-

tude and phase behaviour of the drive units, the location of the drive units with respect to one another and the required filter characteristics. The components used in the network are computed to give the complete loudspeaker system a flat frequency response characteristic.

This required first of all a series of measurements of the drive units and then drawing up a design specification for the filter. Our preference was a fourth-order Linkwitz-Riley filter, because this gives a steep roll-off and allows the loudspeakers to be connected in phase.

The computer calculations resulted in a first-order low-pass section for the subwoofer, a second-order high-pass section for the overall satellite system, a fourth-order low-pass section for the medium-frequency unit, and a third-order high-pass section for the tweeter. Taking into account the natural response of the drive units in their enclosures, these calculations lead to fourth-order slopes in all cases. The cross-over between subwoofer and satellite occurs at 150 Hz and that between medium-frequency unit and tweeter at 3500 Hz. The practical circuit diagrams of the two networks are shown in Fig. 5.

### Construction

It is best to commence the construction with the building of the cross-over filters on the PCBs shown in Fig. 6a (subwoofer) and 6b (satellite). Note that it is imperative that L1 is air-cored and wound from 1 mm dia. enamelled copper wire. An iron core would lower the internal resistance of the coil, causing the overall impedance of the Triplet system to drop below 3 ohms, which is not an acceptable value for a 4-ohm system. It is, of course, also possible to build them on prototyping or vero board (as our prototypes were). The components may then be interconnected at the underside with fairly thick copper wire. Take care that the relevant board fits into the satellite box: it is slid into the enclosure via the larger aperture.

Since the enclosures have fairly regular shapes, their construction is pretty straightforward. The satellite boxes are made from 12 mm chipboard or plywood: they are so small that the material is of no great consequence. In the front panel two apertures should be cut for the drive units and in the back panel a small round or rectangular hole for the connection panel and cable clamps. Before cutting that back panel hole, decide where the filter board is going to be located.

It is strongly advised to secure the drive units with bolts, washers and wingnuts, as this gives a more secure and longer lasting fitting than just wood screws.

When the box is ready with the drive units, filter and connection panel fitted,

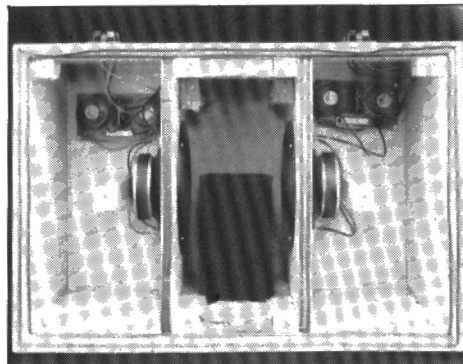


Fig. 4. Inside view of the subwoofer enclosure.

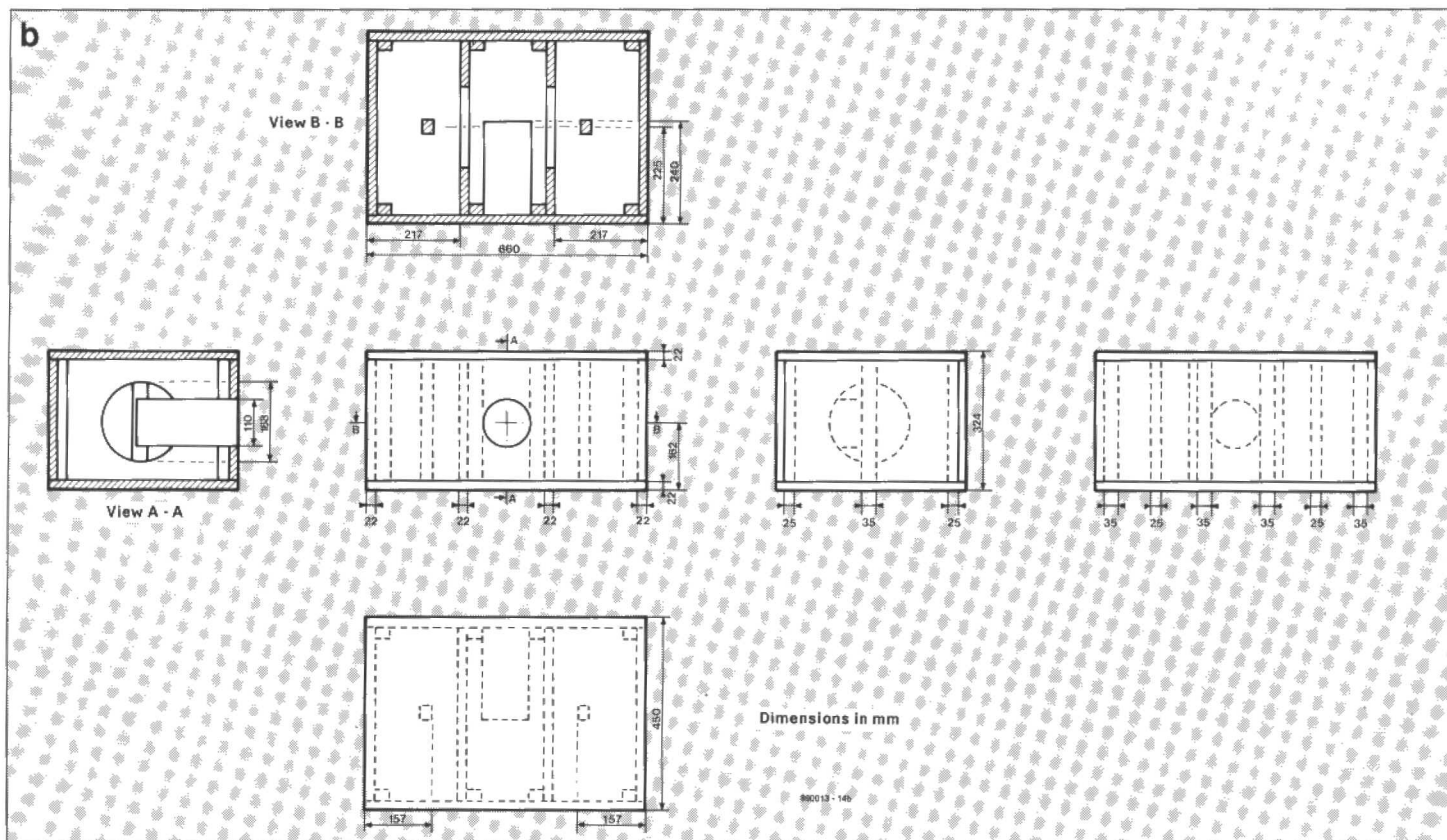
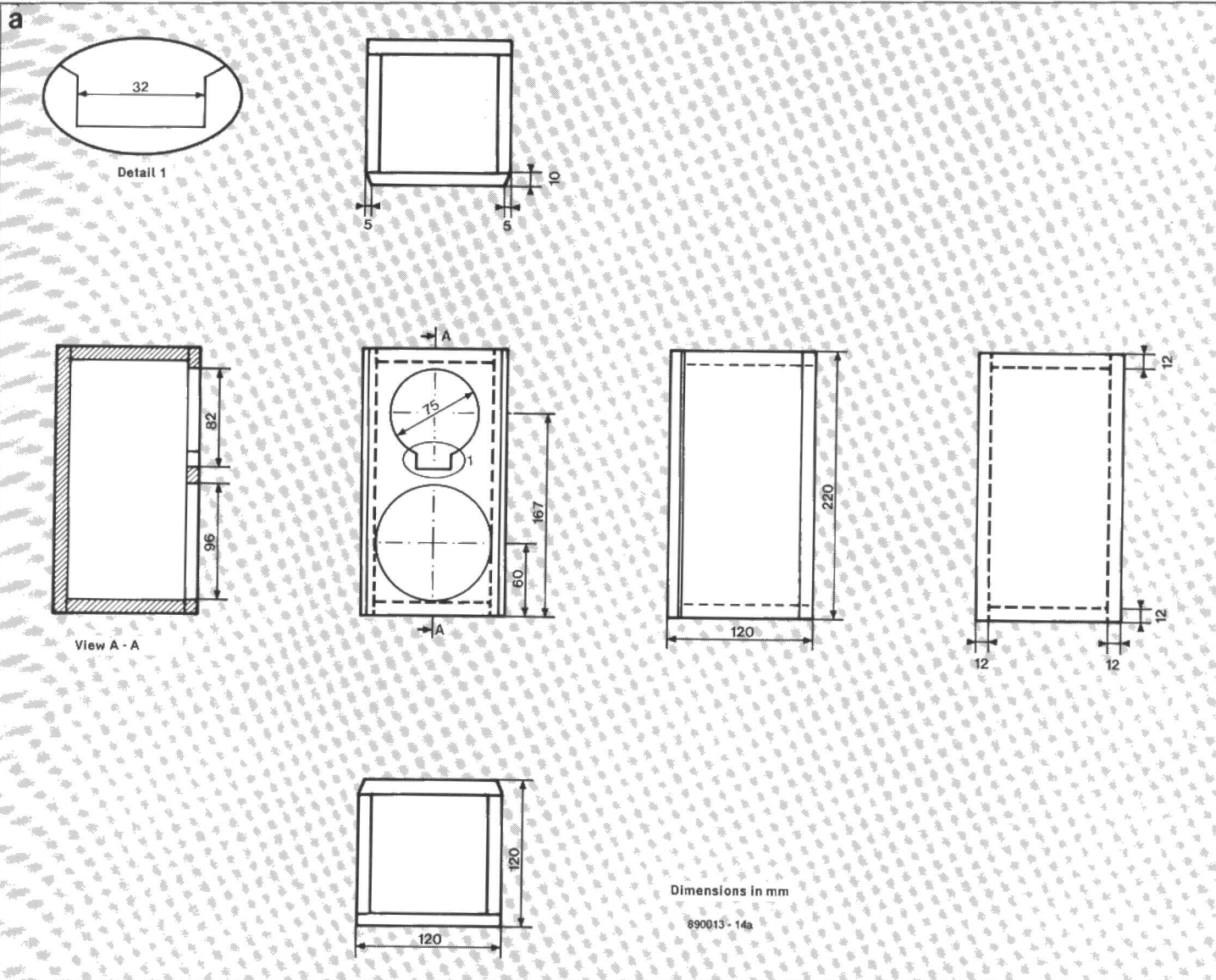


Fig. 7. The construction diagrams for (a) the satellite and (b) for the subwoofer.

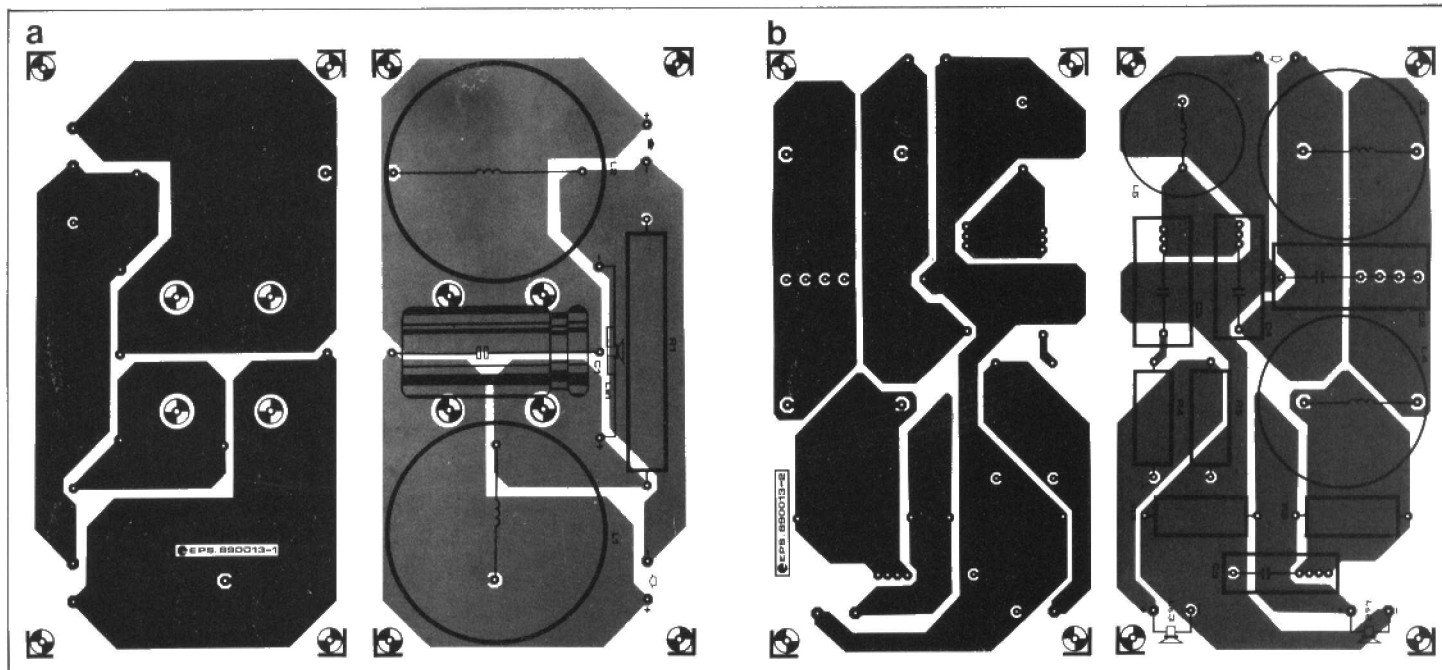


Fig. 6. The PCBs for the filters provide ample room for a variety of components. The subwoofer board is shown in (a) and that for the satellite in (b).

#### Parts list

For a complete system, all quantities must be doubled except where otherwise indicated.

#### Resistors:

R1 = 12 R/9 W  
R2 = 1R2/5 W  
R3 = 12 R/5 W  
R4 = 4R7/5 W  
R5 = 8R2/5 W

#### Capacitors:

C1 = 100 $\mu$ /40 V bipolar  
C2 = 10 $\mu$  MKT  
C3 = 3 $\mu$ 3 MKT  
C4 = 4 $\mu$ 7 MKT  
C5 = 8 $\mu$ 2 MKT

#### Inductors:

L1 = 2.7 mH air-cored (1 mm dia. ECW)  
L2 = 4.7 mH on pot core (1.2 mm dia. ECW)

L3 = 0.56 mH air-cored (1 mm dia. ECW)  
L4 = 0.22 mH air-cored (1 mm dia. ECW)  
L5 = 0.18 mH air-cored (0.71 mm dia. ECW)  
ECW = enamelled copper wire

#### Drive units:

LS1 = SEAS Type CA21 REX4X/DC  
LS2 = SEAS Type 11 F-GX  
LS3 = SEAS Type H 398

The SEAS drive units are imported into the UK by:

Mr. Neil MacKinlay  
High Haven  
Chapel Lane  
Charsfield  
WOODBRIDGE  
Suffolk IP13 7PX  
Telephone (0473) 37345

#### Miscellaneous:

2 connecting panels for woofer

1 connecting panel for satellite  
polyester wool  
glass wool or rock wool  
some felt  
1 PVC tunnel (pipe) outer dia. 110 mm, length 240 mm (only 1 required)  
nuts, bolts and washers as required

#### Box materials:

12 mm chipboard or plywood:  
2 panels 220  $\times$  120 mm  
2 panels 196  $\times$  96 mm  
2 panels 120  $\times$  96 mm

22 mm chipboard or plywood:  
4 panels 406  $\times$  280 mm  
2 panels 660  $\times$  280 mm  
2 panels 660  $\times$  450 mm

stiffening struts for woofer enclosure

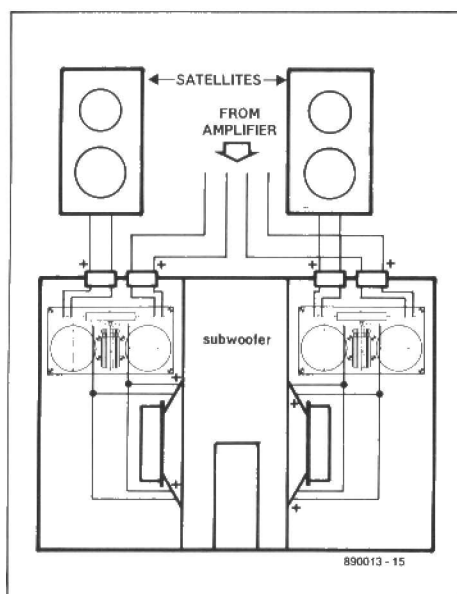


Fig. 8. Wiring diagram of the Triplet loudspeaker system.

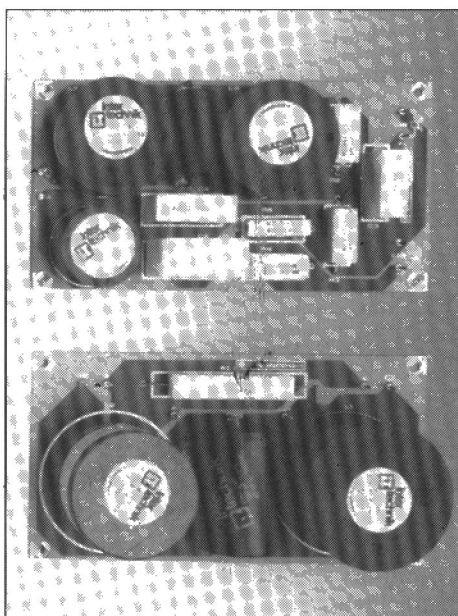


Fig. 9. The two completed PCBs.

#### Technical data

Frequency range	30 Hz — 20 kHz (-3 dB)
Sensitivity	84 dB (1 W/1 m)
Cross-over filter	4th order Linkwitz-Riley
Cross-over frequencies	150 Hz and 3500 Hz
Dimensions	subwoofer: 660 $\times$ 450 $\times$ 324 mm satellite: 220 $\times$ 120 $\times$ 120 mm
Net volume	subwoofer: 65 litres satellite: 1.5 litre
Power handling	80 W (complete system)
Nominal impedance	4 $\Omega$

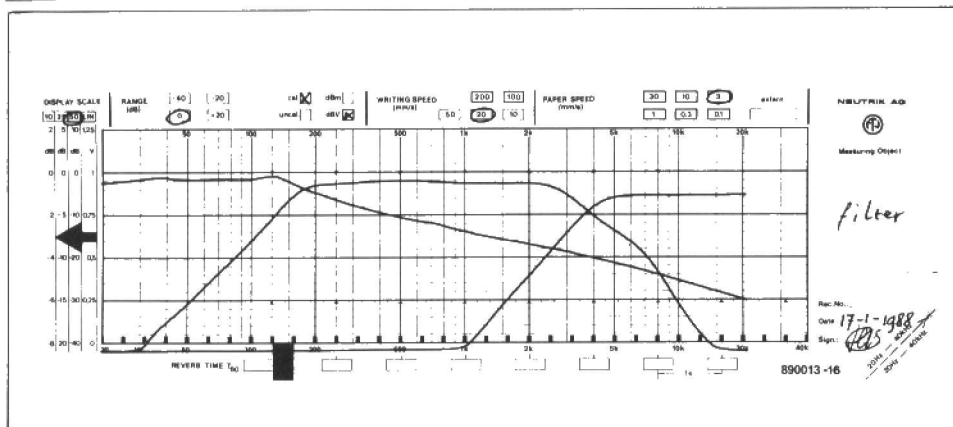


Fig. 10. Voltage vs frequency characteristics at the various filter outputs.

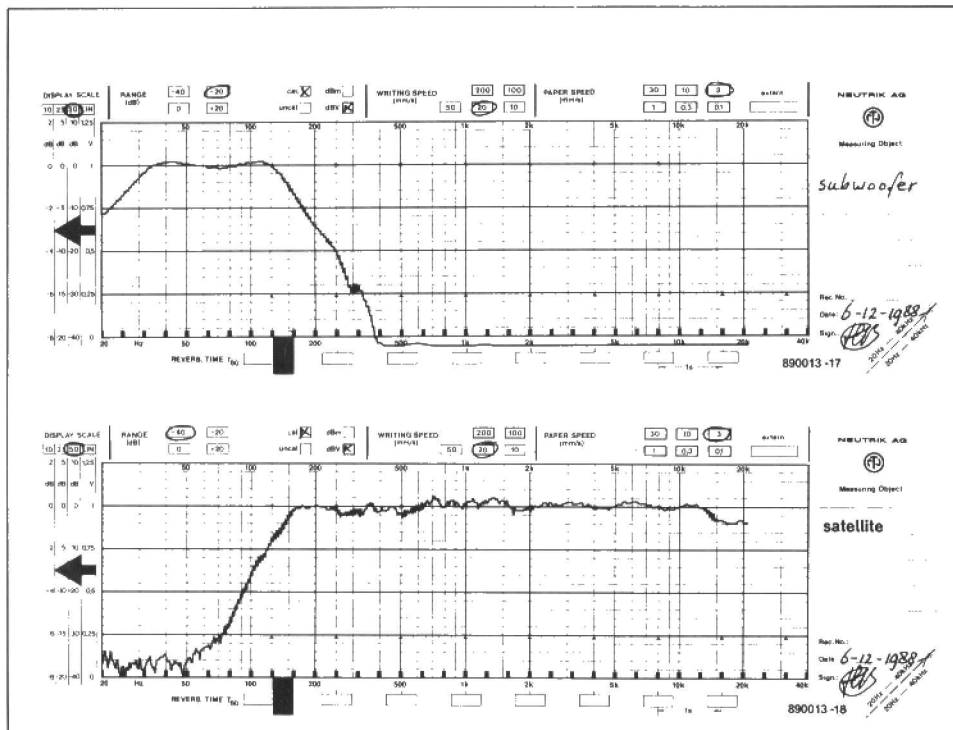


Fig. 11. Frequency response characteristics of (a) the subwoofer and (b) the satellite, measured with the cross-over filters in circuit.

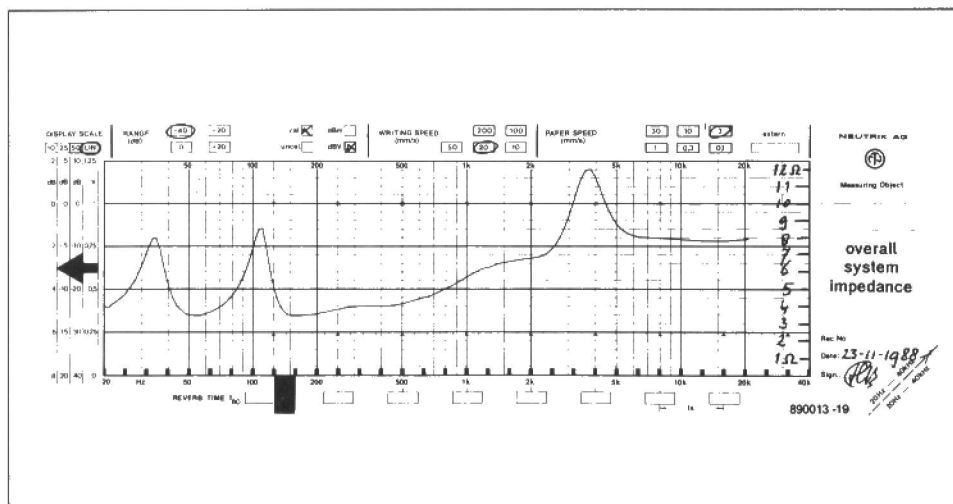


Fig. 12. The impedance characteristic of the overall Triplet system. Nowhere does the impedance drop to below 3.5 ohms.

fill it loosely with polyester wool before screwing the last panel into place. The subwoofer enclosure should be made from 22 mm chipboard or

medium-density fibre board (MDF). As already mentioned, the indicated dimensions are not sacrosanct, as long as the internal net volumes and the vent keep

their specified values. It is recommended to fit inside the enclosure some stiffening struts, particularly between top and bottom panel just behind the drive units: this will prevent those panels from vibrating.

Start by fitting the drive units on to the centre chamber before gluing the PVC tunnel into the relevant aperture. The speech coils of each drive unit are interconnected with the aid of stout copper wire. Take care to connect them in phase, that is, positive terminal to positive terminal.

The subwoofer filters are fitted on to the inside bottom panel of the relevant closed chamber. The long side panels of the box are each provided with two connection panels: one for the audio input signal and one to feed the filtered signal to the satellite.

For damping material in the closed chambers use polyester wool (well packed). A piece of glass wool or stone wool is glued to the short side panels of the central chamber, another piece around the tunnel aperture, and a fourth piece to the panel opposite the tunnel aperture. The PVC tunnel should be covered with a layer of felt. After all wiring has been put into place, the box may be closed.

The construction diagrams for the enclosures are given in Fig. 7a (satellite) and 7b (subwoofer).

Figure 8 shows the inter-wiring of the Triplet system.

## Positioning and use

The reproduction of medium and low frequencies by small loudspeaker enclosures is problematic. The Triplet satellite boxes have a frequency response that gently falls off towards the lower frequencies from about 1 kHz. This behaviour is typical of small boxes. It is, therefore, not recommended to place the satellites loose on a shelf (or suspend them from the ceiling as one manufacturer recommends (sic)). This would result in fairly poor reproduction of the lower medium frequencies, and particularly cause loss of character and quality of speech.

It is best to place the satellites in a book case, or on a book shelf, in between some fairly heavy volumes. The frequency response characteristic in Fig. 11b was obtained from satellites so positioned.

The subwoofer should stand on the floor, preferably on some short feet to prevent direct contact with the floor. The position of the box is not critical and is probably best determined in each individual case to personal taste. The box has, however, a preference for being placed against a wall.

# APPLICATION NOTES

The contents of this column are based on information obtained from manufacturers in the electronics industry, or their representatives, and do not imply practical experience by *Elektor Electronics* or its consultants.

## DYNAMIC RANGE PROCESSOR TYPE SSM2120/2122

Integrated circuit Type SSM2120 from Precision Monolithics Inc. is a dynamic range processor designed specifically for use in professional audio systems. The chip, housed in a 22-pin 'skinnydip' package, has two fully independent class A voltage controlled amplifiers (VCAs) that exhibit very low distortion and offer a 100 dB dynamic range. Each VCA has two complementary antilog (dB/volt) control ports to simplify system design. Also included on the chip are two independent control side chain circuits, each of which consists of a full-wave rectifier, a logging circuit, and a high-impedance amplifier. The log/antilog nature of the control paths makes poss-

ible precisely defined compression/expansion ratios over a 100 dB dynamic range.

The SSM2122 is the same die offered in a 16-pin package for use as a dual VCA without the level detection circuitry accessible.

### Voltage controlled amplifiers

The two VCAs in both the SSM2120 and the SSM2122 are full class A current in/current out devices with complementary dB/volt gain ports. For best performance, these pins should be connected to ground with resistors valued at 200 $\Omega$  or less. Control sensitivities at the

pins are  $\pm 6$  mV/dB. The resistor to ground forms part of an attenuator that determines the sensitivity of the VCA to a control voltage source.

The signal inputs are virtual grounds and the outputs are designed to be connected to the virtual grounds of operational amplifiers configured as current-to-voltage converters. The input/output current compliance range is determined by the current into the reference current pin (pin 10 for the 2120 and pin 7 for the 2122). The voltage at the pin is about two volts above the negative supply. A resistor can be connected from the pin to the positive supply with a value that determines the current into the pin. The current consumption of the device will be directly proportional to this current which should be nominally 200  $\mu$ A. Smaller values can be chosen for battery operation at the expense of a lower dynamic range from the VCAs. With a 200  $\mu$ A reference current, the input/output current clip point at unity gain will be  $\pm 400$   $\mu$ A. In the general case

$$I_{clip} = \pm 2I_{ref}$$

This, together with the power supplies used, determines the value of input and output resistors for optimum dynamic range. For example, with  $\pm 15$  V supplies,

$$400 \mu A \times 36 k = 14.4 V$$

which coincides with the output clip points of the opamps.

The CFT pins are optional control feedthrough null points that are required in some applications, most notably noise gating and downward expansion. The trim procedure is to apply a sinusoidal signal at 100 Hz to the control point attenuator whereby its peaks correspond to the VCAs' maximum intended gain and at least 30 dB of attenuation. The trimpot is then adjusted for minimum feedthrough. With 36 k $\Omega$  input and output resistors, the trimmed control feedthrough is typically well under 1 mV r.m.s. This adjustment may not be re-

### PRELIMINARY SPECIFICATIONS\*

Operating Temperature: -10°C to +55°C; Storage Temperature: -55°C to +125°C

The following specifications apply for @VS =  $\pm 15$ V, T<sub>a</sub> = 25°C, I<sub>ref</sub> = 200  $\mu$ A

PARAMETER	MIN	TYP	MAX	UNITS	CONDITIONS
<b>General</b>					
Positive Supply Range	+5		+18	V	
Negative Supply Range	-18		-5	V	
I <sub>CC</sub>		8	10	mA	
I <sub>EE</sub>		6	8	mA	
<b>VCA's</b>					
Max I <sub>signal</sub> (in/out)	$\pm 387$	$\pm 400$	$\pm 413$	$\mu$ A	
Output Offset		$\pm 1$	$\pm 2$	$\mu$ A	
Control Feedthrough (trimmed)		750 $\mu$ V			
Gain Control Range	-100		+40	dB	Unity Gain
Control Sensitivity		6		mV/dB	
Gain Scale Factor Drift		-3300		ppm/°C	
Frequency Response		250		kHz	Unity Gain or less
Off Isolation		100		dB	@ 1KHz
Current Gain	-0.25	0	+0.25	dB	V <sub>e+</sub> = V <sub>e-</sub> = 0V
THD (Unity Gain)		0.005	0.02	%	+ 10dBV In/Out
Noise (20KHz Bandwidth)		-80		dB	RE: 0dBV
<b>Level Detectors (2120 only)</b>					
Dynamic Range	100	110		dB	
Input Current Range	0.03		3000	$\mu$ A <sub>pp</sub>	
Rectifier Input Bias Current		4	16	nA	
Output Sensitivity		3		mV/dB	
Output Offset Voltage		$\pm 0.5$	$\pm 2$	mV	
Frequency Response:					
I <sub>IN</sub> = 1mA <sub>pp</sub>		1000		KHz	
I <sub>IN</sub> = 10 $\mu$ A <sub>pp</sub>		50		KHz	
I <sub>IN</sub> = 1 $\mu$ A <sub>pp</sub>		7.5		KHz	
<b>Control Amplifiers (2120 only)</b>					
Input Bias Current		85	175	nA	
Output Drive (Max Sink Current)	5.0	7.5		mA	
Input Offset Voltage		$\pm 0.5$	$\pm 2$	mV	

\*Specifications are subject to change without notice.

quired in compressor/limiter applications because the VCA operates at unity gain unless the signal is large enough to initiate a gain reduction, in which case the control feedthrough is masked by the signal. The trim is ineffective for voltage controlled filter circuits. Typical THD and noise performance characteristics are given in Fig. 1 and Fig. 2 respectively. Leave the CFT pins open if unused.

### Control sections (2120 only)

The 2120 has two separate control sidechain circuits, each of which consists of a wide dynamic range full-wave rectifier and logging circuit followed by an amplifier with unipolar drive. The rectifier input has a d.c. voltage of about 2.1 V above ground, so that for proper operation a low-leakage blocking capacitor is required in series with the input resistor. The resistor should be chosen to give a  $\pm 1.5$  mA peak input signal. When operating from  $\pm 15$  V supplies, this corresponds to a value of 10 k $\Omega$ . The detector will provide accurate level information over a dynamic range from 3 mA to 30 nA peak-to-peak, or about 100 dB. The logarithm of this level information appears at the LOGAV pin(s) where it can be averaged with a capacitor connected to ground. The voltage at the pin is no more than a few hundred millivolts above or below ground.

The output transistor is run at a constant current. This is accomplished by connecting a resistor from the LOGAV pin to the negative supply. With  $\pm 15$  V supplies, a 1.5 M $\Omega$  resistor will establish a 10  $\mu$ A reference current in the transistor which is the middle of the detector's dynamic current range in dB. This is also about the optimum value for the dynamic range and accuracy.

The LOGAV outputs are buffered and amplified by unipolar drive opamps. A 39k-1k resistor network connected between the output, threshold pin (inverting opamp input) and ground provides an amplification of 40.

An attenuator from the output to the appropriate VCA control port establishes the control sensitivity.

### Applications of the 2120

The threshold control pin and the negative-going unipolar output are useful in dynamic filter, downward expander, and noise gating applications — see Fig. 3.

Adding a resistor from the opamp output to the positive supply will make the drive bipolar for compandor circuits — see Fig. 4. The value of the resistor may be chosen to determine the maximum output from the control amplifier. By modifying this circuit with a couple of diodes, one can obtain a unipolar drive in the positive direction. This is useful in

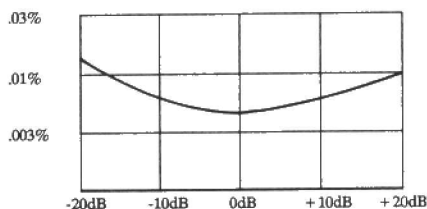


FIGURE 1A: VCA THD PERFORMANCE VS. GAIN (+10dBV IN/OUT @ 1kHz).

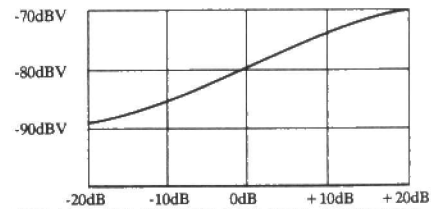


FIGURE 1B: VCA NOISE VS. GAIN (20kHz BANDWIDTH).

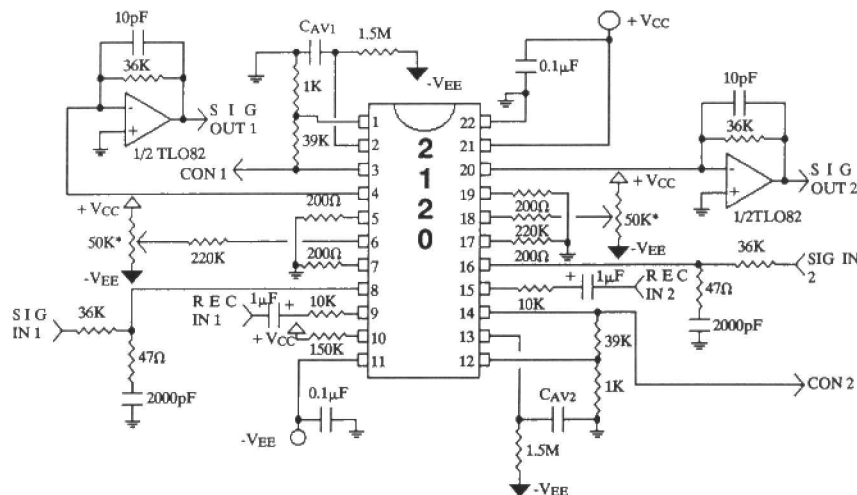


FIGURE 2: 2120 BASIC CONNECTION AT  $V_S = \pm 15$  V (CONTROL CIRCUITS UNCOMMITTED). \*OPTIONAL CONTROL FEEDTHROUGH NULL ADJUSTMENTS.

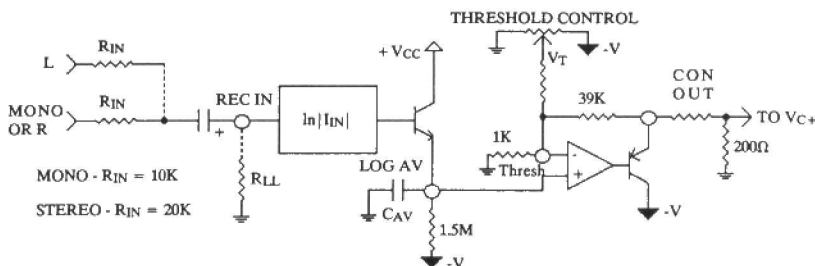


FIGURE 3: NOISE GATE/DOWNWARD EXPANDER CONTROL CIRCUIT.

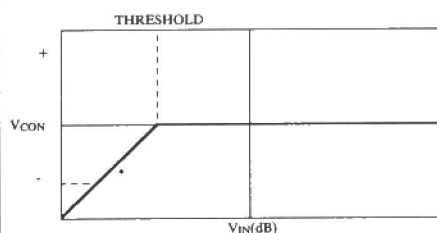


FIGURE 3A: TYPICAL DOWNWARD EXPANDER CONTROL CURVE. \*LOWER LIMIT CAN BE FIXED BY CONNECTING A RESISTOR  $R_{LL}$  FROM REC IN TO GROUND.

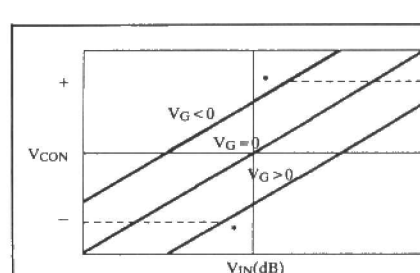


FIGURE 4A: TYPICAL COMPANDOR CONTROL CURVES. \*UPPER AND LOWER LIMITS CAN BE ESTABLISHED BY VALUES OF  $R_{PV}$  AND  $R_{LL}$ , RESPECTIVELY.

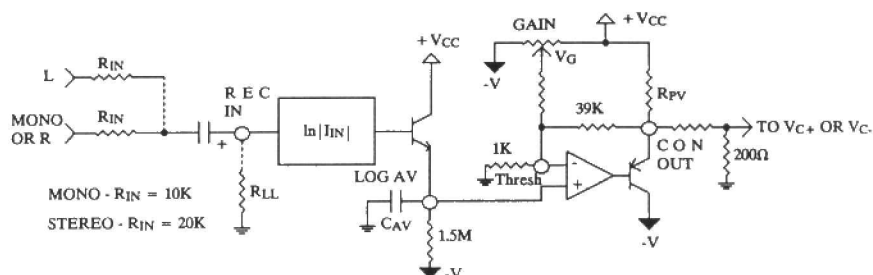


FIGURE 4: COMPANDOR CONTROL CIRCUIT.

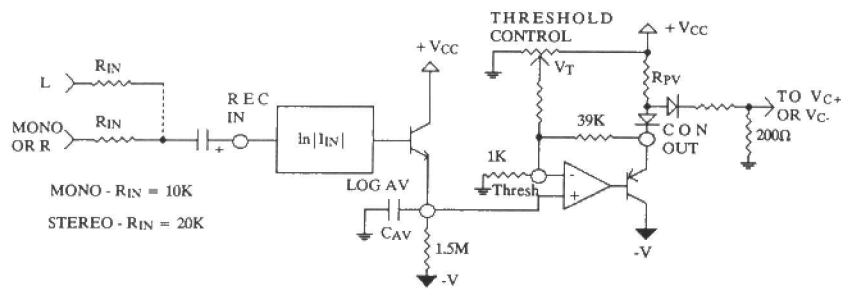


FIGURE 5: COMPRESSOR/LIMITER CONTROL CIRCUIT.

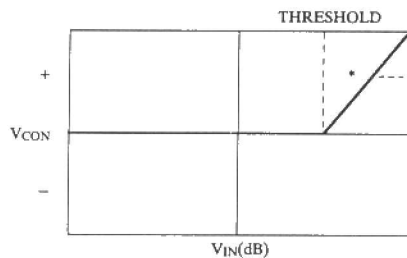
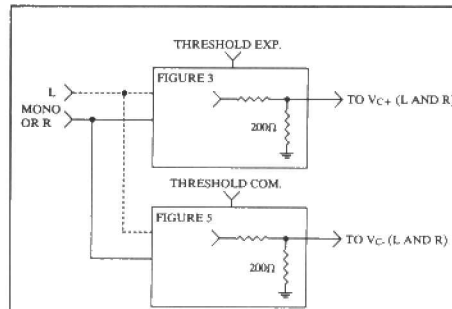
FIGURE 5A: TYPICAL COMPRESSOR/LIMITER CONTROL CIRCUIT. \*UPPER LIMIT CAN BE FIXED BY VALUE OF PULL UP RESISTOR ( $R_{PV}$ ) CONNECTED TO POSITIVE SUPPLY.

FIGURE 6: CONTROL CIRCUIT FOR STEREO COMPRESSOR/LIMITER WITH NOISE GATING.

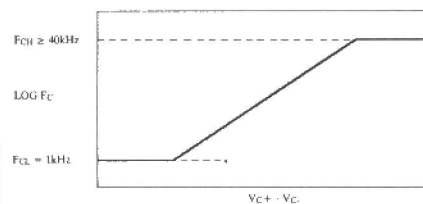


FIGURE 7A: DYNAMIC NOISE FILTER CONTROL CURVE. \*FILTER WILL CLOSE DOWN TO MINIMUM FREQUENCY WHEN INPUT SIGNAL AMPLITUDE IS BELOW THRESHOLD.

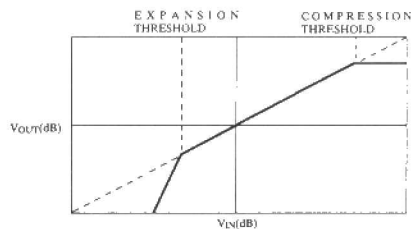


FIGURE 6A: INPUT/OUTPUT CURVE FOR CIRCUIT OF FIGURE 6.

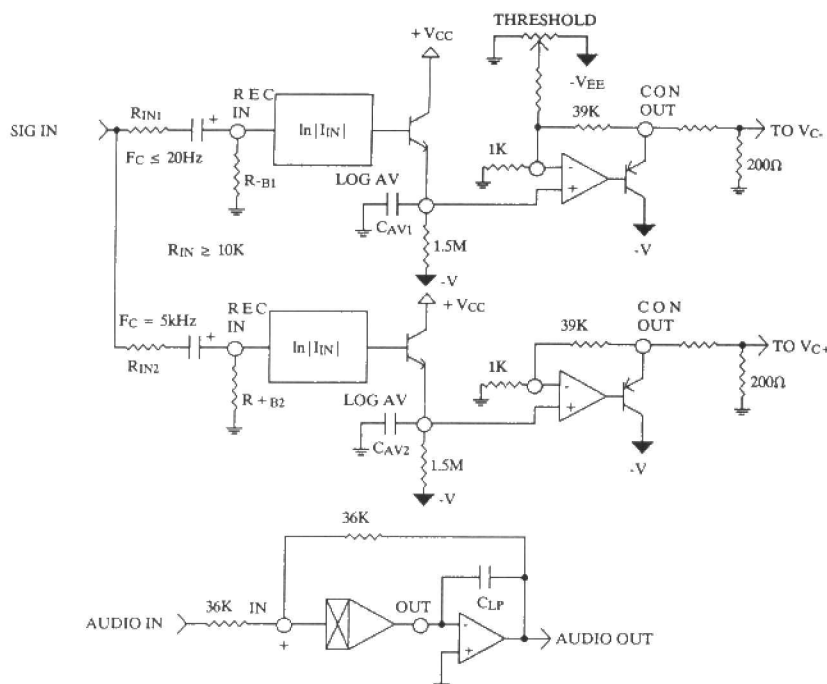


FIGURE 7: DYNAMIC NOISE FILTER CIRCUIT.

compressor/limiter applications — see Fig. 5.

The threshold control circuits shown in Figs 3, 4, and 5 can be used to control the signal level versus control voltage characteristic and/or the onset of control action in the case of Figures 3 and 5. The 1 kΩ and series resistor from the threshold pin to the threshold control pot determine the sensitivity of the control.

The two control circuits can also be used in conjunction to produce composite control voltages. Fig. 6 shows such a circuit for a stereo compressor/limiter that also acts as a downward expander for noise gating. In the absence of a signal, the output noise will be determined by the opamp used in the output current-to-voltage convertors if the expansion ratio is high enough.

Fig. 7 shows a control circuit for a dynamic filter that can be used in single-ended (non-encode/decode) noise reduction. Such circuits usually suffer from a loss of high-frequency content at low signal levels since the control circuit detects the absolute amount of highs present in the signal. Fig. 7 measures the relative amount of highs in the signal by effectively producing a composite control voltage which is the difference between the absolute amount of highs and the full audio band signal level. The values of the RB resistors establish a default signal level (for instance -30 dBV to -50 dBV) below which the filter(s) will start to close down to their minimum bandwidth, which should be about 1 kHz. This minimum cut-off frequency is determined by the value of the filter capacitor and the ratio of the RB resistors.

The 2120 can also be used in VCA fader automation systems to serve two channels. The inverting control port is connected through an attenuator to the VCA control voltage source\* and the non-inverting control port is connected to a Fig. 3 control circuit that senses the input signal level to the VCA. Above the threshold voltage which can be set quite low (say, -50 dBV or -60 dBV), the VCA operates at its programmed gain. Below this threshold the VCA will downward expand at a rate determined by the  $V_{C+}$  control port attenuator. By keeping the release time constant in the 10 to 25 millisecond range, the noise floor modulation, which is -82 dBV maximum, can be kept inaudible.

\*The SSM2300 8-Channel Multiplexed Sample and Hold IC makes an excellent controller for VCAs in automation systems.

Further information on these products may be obtained from

**Bourns Electronics Ltd • Hadford House • High Street • HOUNSLOW TW3 1TE • Telephone 01-572 6531**

# THE NATIONAL SOUND ARCHIVE

The National Sound Archive is a unique resource centre for the study of all kinds of music, literature, social and zoological sciences, and a prime source for broadcasters, film-makers, theatre companies, advertising agencies, the record industry and the general public. It holds around three quarters of a million discs, over 45,000 hours of tape recordings and a growing collection of specialist video materials.

## Historical background

The National Sound Archive was originally known as the British Institute of Recorded Sound. It became a department of the British Library in 1983, when it took on its present title.

In 1955 the British Institute of Recorded Sound acquired its first real home at 38 Russell Square, a building loaned to it by trustees of the British Museum. Members of the original board of governors included Sir Adrian Boult and Desmond Shawe-Taylor. In 1966, the British Institute of Recorded Sound moved to its present site at 29 Exhibition Road and was officially opened in 1968 by Jennie Lee.

The British Institute of Recorded Sound was initially orientated towards the Golden Age of Opera and to classical music. As tape recording increased the range of subjects that could be recorded, the Institute developed a comprehensive policy towards collection, which is still followed today.

## National Sound Archive collections

The National Sound Archive holds copies of all current commercial records (including compact discs), as well as a vast catalogue of recordings from as early as the 1890s, many of which are not available anywhere else.

The earliest recordings of famous voices include Florence Nightingale, Gladstone, Tennyson and Browning; Brahms playing Brahms in 1889; and James Joyce reading from *Ulysses* in 1924. Other early voice recordings include those made of Aboriginal chants in the Torres Straits off Tasmania. These were made on wax cylinder in the 1890s, and collected by Sir James Frazer when he was writing *The Golden Bough*.

The Archive houses a wide range of broadcast materials, including a complete duplicate collection of BBC Sound Archives recordings. There are also thousands of hours of unique unpublished recordings, and a growing collection of videos.

The subjects covered include recordings

of all kinds of music, from classical and jazz to traditional and pop music from all over the world, and spoken word recordings, from political speeches to theatre performances, including many writers reading and discussing their own work. There are also significant collections of oral-history recordings, sound effects, documentary and industrial-mechanical sounds and natural and wildlife sounds.

The music collections span the whole range of performances and composition styles, with a century of published records and tapes from all parts of the globe.

**Classical Music** This represents one of the Archive's major collections; comparative research into differing interpretations is easily arranged. Many recordings of BBC broadcasts have been specially made by the Archive and are not available for reference anywhere else; these constitute an important source, particularly for the study of contemporary classical music.

Access can also be arranged at the Archive to over 80,000 musical scores held at the British Library Document Supply Centre at Boston Spa.

**Popular Music** This ranges from early music hall to eighties' hip-hop, and extends to a wide range of styles from many different countries. Live performances recorded by the Archive may be heard, as well as many other recorded interviews, talks and seminars. A fast-growing collection of commercial and promotional videos is also featured.

**Jazz** All styles, from all periods and locations, are well represented, as are the related styles of ragtime, dance bands and blues. There is a good collection of free improvised jazz. There is also a growing collection of unique interview material, including the National Sound Archive Oral History of British Jazz.

**Traditional Music** This has been gathered from all parts of the world, especially Africa and South Asia. The collection contains records and cassettes published in the country of origin, and includes a wide range of European and North American labels specialising in traditional music, as well as unique collections of unpublished 'field recordings', representing important research on many different musical styles. There is also a small but expanding selection of archival videos, particularly of visiting musicians from overseas.

**The Recorded Literature and Theatre Collection** A large number of unique recordings of twentieth-century writers, reading and talking about their own work, are held in this collection. It offers especially rich resources for the study of

literature in English, including work from Africa, the Caribbean and North America.

The collection holds many live theatre recordings made over 25 years, including performances at the National Theatre, the Royal Shakespeare Company, the Royal Court and Riverside Studios, as well as at the Edinburgh Fringe and provincial theatres. There are also recordings of performances by foreign companies. Other theatrical recordings include workshops, discussions and interviews with leading actors, directors and playwrights.

The majority of these are unpublished recordings and represent a major research resource. Anyone working on contemporary literary texts will find useful additions to their material at the Archive. With good coverage of American radio serials and extensive holdings of BBC and other British radio stations' output, the Archive is also an important resource centre for research into radio.

**The Language and Dialect Collection** A wide range of commercially issued language courses and foreign language recordings are held. Many samples of social and regional speech variations from Britain and Eire are also available.

**Oral History** Materials include many significant interviews on the history of the record and sound broadcasting industries, and also historic collections such as that of the pioneer oral historian, George Ewart Evans.

**Recordings of Parliamentary Sessions** Recordings are available from the House of Lords, the House of Commons and Select Committees. Tapes are deposited here after seven years.

Worldwide in scope, the collection includes tapes from professional zoologists and amateur recordists, BBC natural history recordings, and commercially issued discs and cassettes. Over 5,000 species of birds, mammals, amphibians, insects and other animals are represented. The recordings in the collection range from the very earliest, for example those made by the pioneer Ludwig Koch in the 1890s to others using modern digital and ultrasonic techniques.

A wide range of commercially issued recordings of authentic sounds are supplemented by a growing collection of field recordings made by the Archive. The collections extend from recordings of motorised transport from the first decades of the twentieth century, through actuality recordings — for example, of factory and machine sounds — to original sound effects recorded in the field.

## Catalogues

Many catalogues are available for reference, but two principal sources provide quick, accurate and immediate assistance: the *National Discography* and the *National Sound Archive general catalogue*.

The National Sound Archive is a major participant in the compilation of the *National Discography*. This new data base will give details of all commercial discs currently available in the United Kingdom; the Archive's own computerised catalogue covers its non-commercial recordings.

The National Register of Collections of Recorded Sound is a data base providing details of recordings, listening facilities and associated collections in hundreds of other organisations and institutions in the United Kingdom. Subject searches can be carried out, or particular regional holdings can be explored.

## Services

Individual listening-desks with headphones are provided for study, and there is a group listening room which can accommodate parties of up to 15 people. There is also a separate room, bookable on request, where one or two individuals can listen over loudspeakers. Video viewing is also available for one or two people at a time.

The library offers a wide range of catalogues, discographies, periodicals and monographs which cover every

aspect of recorded sound. These include catalogues of the BBC Sound Archives, BBC song title indexes, and such well-known international catalogues as *The Gramophone*, *Bielefelder*, *Diapason* and *Schwann*. Periodicals include back copies of the *Radio Times*, *The Listener* and music publications such as *Early Music* and *Melody Maker*. The library functions as a main source of finding-aids for recordings and represents a major documentary resource in its own right.

**Information Service** Visitors should go first to the Information Service in the library. Members of staff can give assistance with preliminary research into the location of particular recordings, advise on availability, and provide information about manufacturers or distributors.

Tape copies can be supplied of deleted commercial discs and other recordings (in analogue or digital format) provided that the appropriate copyright clearances have been obtained.

Spring and autumn series of events are organised regularly and reflect the interests and activities of the National Sound Archive. These usually take place in the Archive's seminar room on Thursday evenings. A programme of events is available on request and a mailing list is maintained.

The Archive welcomes the deposit of private collections and bequests. Please contact the Coordinator of Archive Services for further information.

**Boston Spa** The first local listening post

to be opened is in the reading room of the British Library Document Supply Centre at Boston Spa, near Wetherby, West Yorkshire. Intending users, or those with enquiries about the facility at Boston Spa, should contact the Listening Service in London.

## Access to the collections

The collections of the National Sound Archive are open to everyone. A British Library reader's pass is not required and there is no charge. However, it is necessary to telephone or visit to make an appointment to use the listening and viewing service. A demonstration cassette is nearly always available for first-time visitors to hear without prior arrangement. The reference library is available throughout opening hours.

## How to get there

The National Sound Archive is at 29 Exhibition Road, London SW7 2AS, near the Science Museum and Imperial College.

The nearest Underground station is South Kensington (Piccadilly, District and Circle lines) and many buses stop nearby including numbers 52, 73 and 9. For general enquiries telephone 01-589 6603/4.

The library, listening and viewing services are open Monday-Friday 9.30am to 4.30pm, with late opening to 9pm on Thursday.

# BBC Sound Archive

The BBC's Sound Archive is one of the largest broadcasting collections in the world. Although begun on a systematic basis with the start of radio in the early thirties, the archive has a number of recordings from the pre-broadcasting era. From the thirties onwards the collection has centred on BBC programmes from the golden years of British radio broadcasting.

The Sound Archive now has a quarter of a million recordings, all of which are indexed and cross-referenced. Every year 3,000 hours of new recordings are added, mainly from BBC programme output, but including some specially commissioned material.

The collection covers the whole range of broadcasting — drama, music, comedy, sport, news — from all the radio networks, World Service and local radio. There is a strong emphasis on news and events, at home and abroad. The collection forms an unique sound history of Britain in the twentieth century and an invaluable resource for users of all kinds.

## Services

The Sound Archive licenses recordings

to non-BBC users for broadcasting, commercial, educational or other purposes.

Research and listening facilities are available by appointment at Broadcasting House, London W1 where the collection is located.

Advice and information on copyright clearance is available.

## Copyright

The BBC only takes broadcasting rights in the recordings held by the Sound Archive. For other uses permission must normally be sought from the rights holder or holders. Sound Archive staff can advise and provide information which will enable these clearances to be obtained. Recordings which include copyright music or scripted material may require more complex clearance.

## Advertising

Recordings of BBC contracted staff are not available for use in advertisements. Contracted contributors cannot be used without their consent. However, recordings of actuality, public events and sound effects can often be supplied for

commercials. Check with Archive staff on particular needs; they can usually suggest an alternative where restrictions exist.

## Sound effects

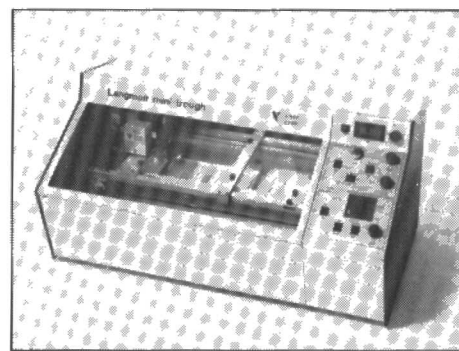
The Sound Effects Library is one of the most comprehensive collections in the world. There are 20,000 recordings of sounds, ranging from World War II through natural history to comedy and these include the most up-to-date effects used in the making of radio and television programmes. Up to a thousand new recordings are added to the collection each year. Recordings can be in mono, stereo or binaural, and the most recent have been digitally processed. The collection is almost entirely BBC Copyright and effects are therefore available for use in any context. For all sound archive or sound effects recordings telephone or write to:

Norma Jones  
BBC,  
Room 5058,  
Broadcasting House,  
London W1A 1AA  
Telephone: 01-927 4853

# SCIENCE & TECHNOLOGY

## Big strides in molecular electronics research

by Dr Mike Petty and Professor Jim Feast  
Directors, Centre for Molecular Electronics, University of Durham



The recently established Centre for Molecular Electronics<sup>(1)</sup> at Durham University initially will have no formal structure and will act to support and promote research activities in this strategic and highly interdisciplinary subject.

Molecular electronics is generally concerned with the exploitation of organic materials in electronic and optoelectronic devices. Durham has a considerable expertise in this and an excellent research record; much of the work involves collaboration between members of the School of Engineering and Applied Science and the Department of Chemistry.

Examples of current research projects include organic conductors, pyroelectric materials, non-linear optics and Langmuir-Blodgett (LB) films.

The value of polymers in the established technologies of the electrical and electronics industries is based primarily on their utility as structural materials and/or insulators. There are many well-known examples including wire insulation, circuit boards, and instrument or device cases — where a wide range of thermosets and thermo-plastics have been used.

### Exciting new project

A rather less widely appreciated application of polymers is based on the formation of composite materials between essentially insulating polymers and conductive particles — carbon blacks or metals. These composite conductive polymers have been in use for well over a century and are the basis of several well established applications: for example, low conductivity materials employed in the discharge of static electricity; in shielding; in self-regulating heating tapes and thermal fuses; and in polymer thick film technology for electronics.

More recently, a lot of excitement and research activity has been generated by the report that the conductivity of the simple hydro-carbon homopolymer,

polyacetylene, can be changed from that of an insulator or semiconductor to that of a metal by oxidation or reduction.

Many other polymers have now been shown to exhibit this behaviour and the initial observations have led to a strong interest in the possibility of using organic materials in electronic or optical devices. However, most of the interesting polymers are not soluble in readily available solvents and are also infusible — factors that severely inhibit their proper structural characterization, purification, and use in devices.

Clearly, any significant work on the problems of applying organic polymers as active components in electronic devices requires methods for the reproducible production of well-characterized pure materials. Chemists in Durham have concentrated on this aspect with some notable successes.

### Poor characteristics

The synthesis, by Professor Feast's group in 1979, of solution processible precursor polymer for polyacetylene has proved to be a major advance in the control of conducting polymer processing, which in turn has important consequences for polymer device physics. Using the novel method, coherent films of polyacetylene with thicknesses in the range 20 nm to 1000 nm can be deposited in configurations appropriate for device studies.

Several workers have demonstrated that conducting polymers may be used as semiconductors in devices, but that the processing difficulties result in these demonstrator devices having disappointingly poor characteristics. For example, Schottky and p-n diodes have been constructed and rectification ratios of a few hundred reported.

In contrast, workers in the Cavendish Laboratory, using samples of polyacetylene produced by the Durham route, have reported routinely obtaining rectification ratios of 500,000 for

Schottky diodes, and "textbook" behaviours for metal-insulator-semiconductor and field-effect transistor structures.

This work was supported by British Petroleum (BP) and the results referred to are part of those obtained in a collaborative study between the Universities of Cambridge, Durham and Sussex and BP's Sunbury Research Centre<sup>(2)</sup>.

### Successful collaboration

LB films consist of layers of organic molecules — just one molecule in thickness — that are assembled on solid surfaces. The LB process allows substances to be manipulated and fabricated at the molecular level; the term "Molecular Lego" is sometimes used. Fundamental physical and chemical processes may therefore be studied; the technique also has many possible technological applications.

A commercial system for the deposition of LB films is currently being sold worldwide by the Joyce Loebel Company<sup>(3)</sup> of Gateshead and is the result of a highly successful collaboration between Durham University, Imperial Chemical Industries (ICI) and Joyce Loebel.

Research currently in progress includes a study of a wide range of novel LB materials and an investigation into the deposition technique itself. However, the research emphasis is on the fabrication of electronic devices incorporating LB films.

In one project, these thin organic layers are being exploited for their non-linear optical properties. The study of the basic science of non-linear optical phenomena in solids and the development of associated devices is vital for advancement of telecommunication technologies. Most attention has been placed thus far on the second order process — the phenomenon responsible for second-harmonic generation — which occurs in inorganic insulators and semiconductors.

## Attractive features

However, there is a rapidly growing interest in organic materials, especially molecular organic crystals because of their very large non-linear coefficients. For example, MNA (3-methyl-4 nitroaniline) has a second harmonic optical figure of merit about 20 times larger than that of lithium niobate. For device fabrication purposes it is desirable to prepare the organic material in thin film rather than bulk crystalline form.

The main aim of this work is therefore to explore the possibility of using LB films in optoelectronics; the natural orientation features of monolayers, the degree of control over molecular architecture, and the precise definition of thickness and refractive index are all attractive features of this approach.

Other work is focused on the development of infrared detectors. The present generation of thermal imaging devices relies mainly on cadmium mercury telluride (CMT). Such devices are bulky, expensive and require cooling; in addition, they have a limited spectral sensi-

tivity. On the other hand, thermal detectors based on the pyroelectric effect have a response that is flat over a broad wavelength range, even when uncooled. It has been shown that the sensitivity of a pyroelectric detector is approximately proportional to the inverse of its thickness; however, electrical breakdown limits the minimum thickness to which conventional detector materials, such as poled polyvinylidene fluoride (PVDF), can be prepared. It would therefore be advantageous to fabricate a pyroelectric detector based on LB films.

## Ongoing research programmes

Pyroelectricity in thick samples consisting of alternate layers of fatty acids and fatty amines and in single monolayers of azo dyes has already been demonstrated. The aim of this project is to find novel materials which can be used to form pyroelectric devices of only a few monolayers thickness.

The foregoing represents only a few of the current research programmes at Durham. Other activities concern

biological membranes, liquid crystal devices, molecular recognition and sensors, and neural networks. Molecular electronics is a very rapidly growing area of research within the United Kingdom. This has been recognized by the Government. Both the Science and Engineering Research Council (SERC) and the Department of Trade and Industry (DTI) have recently announced initiatives to support the work. This will greatly benefit Durham University and other groups in Britain.

1. University of Durham, Centre for Molecular Electronics, Science Laboratories, South Road, Durham DH1 3LE. Telephone: (091 374) 2389.
2. British Petroleum, Sunbury Research Centre, Sunbury-on-Thames TW16 7LN.
3. Joyce-Loebl Ltd, Dukesway, Team Valley, Gateshead, Tyne and Wear NE11 0PZ. Telephone: (091 482) 2111.

## NEW BOOKS

### Physics and Applications of Semiconductor Microstructures

by M. Jaros

ISBN 0 19 851994 X (hardback)

ISBN 0 19 853927 4 (paperback)

Price £30.00 (hardback)

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This work offers two 'firsts'. It is the first in the new 'Series on Semiconductor Science and Technology' and it is the first textbook outlining all key concepts concerning the description and applications of novel semiconductor microstructures such as quantum wells, superlattices, and heterojunction microdevices in general (for instance, lasers, transistors, optical detectors, and switches).

The book bridges the gap between the conventional courses in solid-state physics and electronics, properties of materials and optoelectronics, and the current research publications on semiconductor microstructures. These microstructures will provide a basis for new technologies in electronics and optical communication and have been the subject of growing interest among both academic and industrial researchers.

Only a minimum background knowledge in solid-state physics and quantum mechanics is assumed, so that the book is accessible to undergraduates and first year postgraduates in electronics, materials science, and physics. It

is also suitable for those who wish to become familiar with the basic facts of this new field and whose background is another scientific subject. The descriptive passages can be read in most parts without the mathematics introduced in the first chapters of the book so that the text can also be used as a basis for a low-level lecture course. To that end, it includes over 80 problems with solutions. Clarendon Press • Walton Street • OXFORD OX2 6DP.

### Newnes Guide to TV & Video Technology

by Eugene Trundle

ISBN 0 434 91986 1

432 pages — 185 × 125 mm

Price £8.95 (paperback)

This book is a very worthwhile addition to any technical library. Written by a practising video and TV engineer, it is thoroughly practical in its approach to the subject.

The book represents a breakthrough in terms of value-for-money technical information. Based on two of the most popular Beginners' Guides published by Newnes, *Colour Television* and *Videocassette Recorders*, it brings together in-depth accounts of television and VCR technology.

In twenty-one chapters, over 250 illustrations and over 400 pages, the technicalities of television, video, and allied equipment are lucidly and concisely explained for the benefit of technicians, students, laymen and others. Coverage is wide and deep, extending from the camera lens via videotape

signal processing and deck management to the very latest TV screen technology. It also covers space satellites, microcomputers and such practical matters as videorecorder servicing and maintenance.

Eugene Trundle has a knack of conveying highly technical information in the form of a 'good read'. It is well illustrated in this book.

Heinemann Professional Publishing • Halley Court • Jordan Hill • OXFORD OX2 8EJ.

### Mitel Semiconductor Data Book

The 1989/90 Mitel Semiconductor Data Book is available free from Electronics 2000 Ltd, the well-known distributor for ISDN and digital telecoms devices.

This Volume 6 Data Book contains full details on each of Mitel's telecommunications semiconductors. The book splits into 4 sections covering ISDN and digital telecoms devices; analogue telecoms devices; modem chips; and a comprehensive Application Notes section of over 300 pages.

For further information contact Stan Bembenek at Electronics 2000 Ltd • Grafton House • Grafton Street • High Wycombe HP12 3AJ • Telephone (0494) 444044.

When video tapes are copied directly, some loss of quality is inevitable. The amplifier presented here prevents this deterioration and also provides four separate outputs to make it suitable for use as a distribution amplifier.

One criterion in the judging of the quality of a video recording is the resolution or definition, that is, picture clearness, which is related directly to the bandwidth the video recorder can handle. During re-recording, some deterioration of picture quality occurs because the bandwidth is reduced to a degree that depends on the recording system. This reduction manifests itself primarily in a greater attenuation at the high-frequency end of the signal than at the low-frequency end.

Further loss of quality may occur through a lowering of the overall modulation level, particularly when two or more video recorders, or a video recorder and a colour television monitor, are connected in tandem to the output of the master television receiver or recorder. It would be possible to simply increase the gain of the slave equipment. Unfortunately, maximum frequency-selective amplification and optimum quality can not be achieved by simple means. There would, for instance, be a danger of over-modulation, which would result in a deterioration, rather than an enhancement, of the signal.

The present amplifier provides separate level and modulation (contour) controls, and four independent outputs to enable the simultaneous feeding of up to four video recorders.

### Circuit description

Field-effect transistors T1 and T2 in Fig. 1 form a differential amplifier that offers high input impedance, small phase shift and excellent bandwidth.

The output of the master television receiver or video recorder is applied to the gate of T1 via C1. Resistors R3 and R5, and capacitor C2, serve to determine the d.c. operating point.

The output of T1 is amplified in T3 and push-pull amplifier T4—T5, and then fed back to T2 via R13. The value of R8 ensures that the overall gain is not less than 6 dB.

The feedback (and the carefully designed printed-circuit board) ensures excellent stability in conjunction with good phase behaviour, ample bandwidth, and adequate gain.

Setting of the quiescent current through the output stages is provided automati-

cally by low-capacitance diodes D1—D3 and emitter resistors R16 and R17.

The highly stable video signal is fed to the four outputs via low-reactance electrolytic capacitor C6 and resistors R19—R22.

The AV input of video recorders and monitors is generally terminated by a 68—82  $\Omega$  (nominally 75  $\Omega$ ), so that connection to the present amplifier results in a 6 dB attenuation of the signal. Since the recording amplifier has a gain of not less than 6 dB, the level of the effective input to equipment connected to its outputs is at least equal to that of its own input.

Level-control potentiometer R10 affords additional amplification of the output signal, which is particularly useful if all four outputs are loaded.

Envelope (contour) control R12 enables extra amplification of the high-frequency part of the signal.

The required bandwidth of 50 Hz to 5 MHz is exceeded by a large margin: the power bandwidth of the prototypes stretched from 20 Hz to 25 MHz.

Power requirement of the amplifier is 10—15 V (nominally 12 V) at 50 mA.

The power lines are decoupled by R1 and C7.

Some video recorders have a 12 V output that is ideal for the present amplifier. It is, however, advisable to consult the recorder handbook to make sure that this output can deliver up to 50 mA.

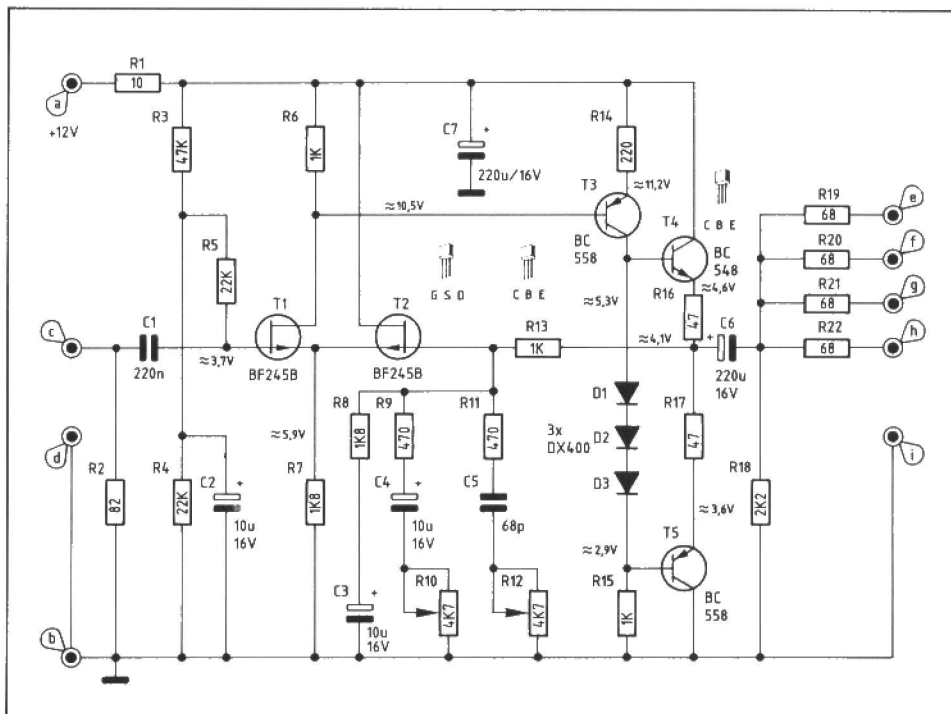
## Construction

It is strongly recommended to construct the amplifier on the ready-made printed-circuit board, since the design of this makes a substantial contribution to the proper operation of the amplifier.

The two potentiometers (R10 and R12) should be mounted on soldering pins (3 each).

Note that points a—i in Fig. 1 correspond to the identically marked ones on the PCB (Fig. 2).

As there is quite a variety of relevant plugs and sockets used in video equipment, the parts list intentionally does not state any particular make. It is best to buy a video recording cable specially made for the relevant VCR together with the matching plug or socket (which is then fitted on to the present amplifier).



**Fig. 1. Circuit diagram of video recording amplifier.**

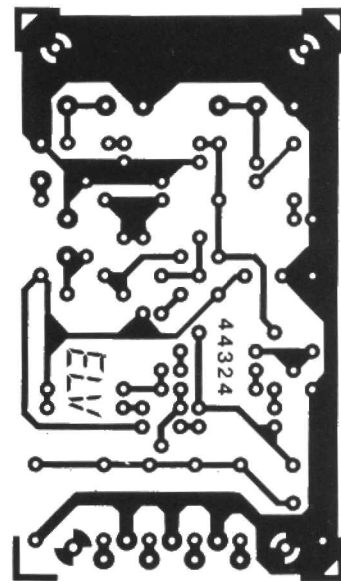
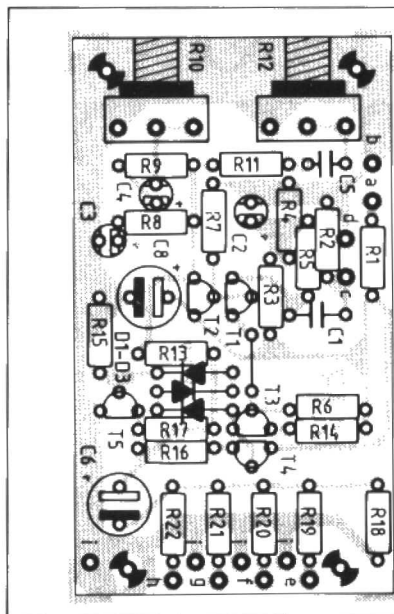
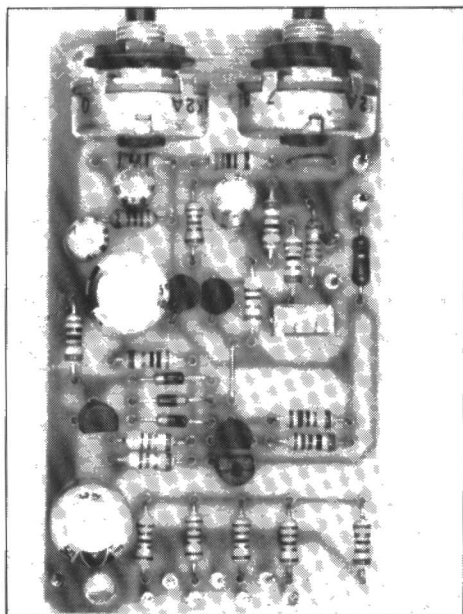


Fig 2. Printed-circuit board for the video recording amplifier.

#### Parts list

##### Resistors:

R1 = 10R  
R2 = 82R  
R3 = 47k  
R4; R5 = 22k  
R6; R13; R15 = 1k  
R7; R8 = 1k8  
R9; R11 = 470R  
R10; R12 = 4k7 linear potentiometer; 4 mm spindle  
R14 = 220R  
R16; R17 = 47R  
R18 = 2k2  
R19—R22 = 68R

##### Capacitors:

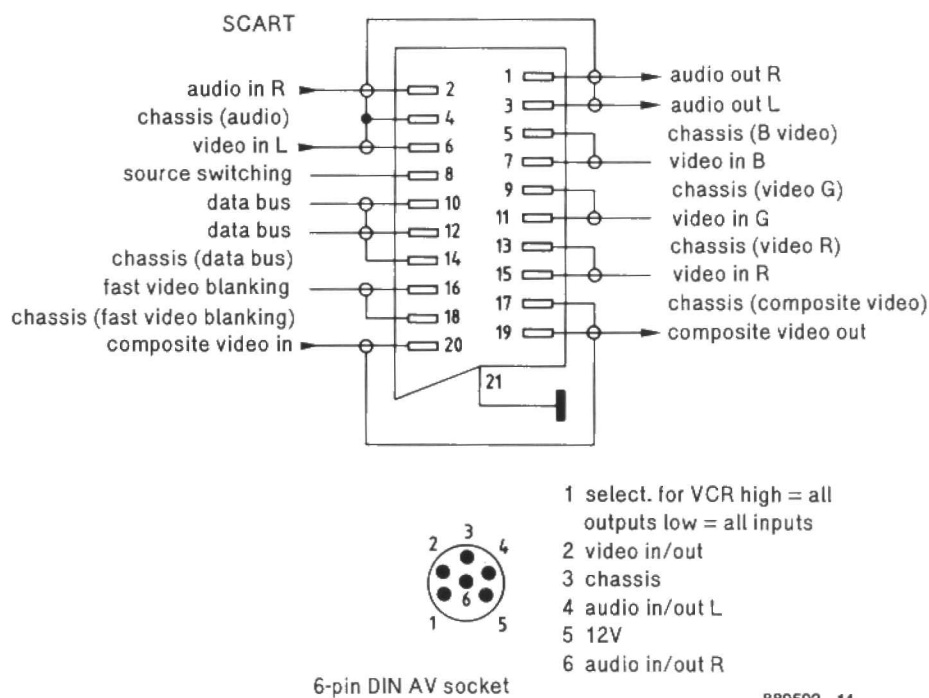
C1 = 220n  
C2—C4 = 10 $\mu$ F; 16 V  
C5 = 68p  
C6; C7 = 220 $\mu$ F; 16 V

##### Semiconductors:

T1; T2 = 8F245B  
T3; T5 = 8C558  
T4 = 8C548  
D1—D3 = DX400

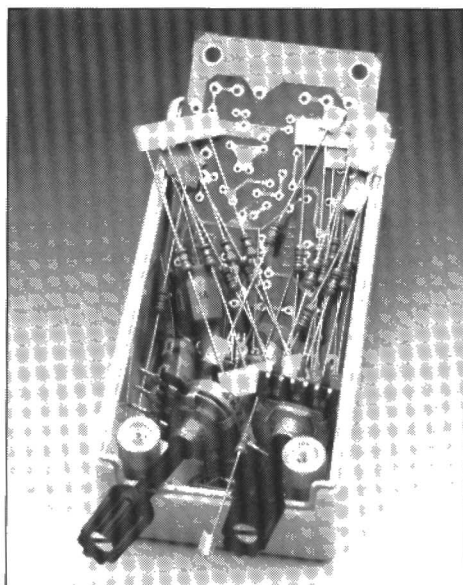
##### Miscellaneous:

9 soldering pins  
2 push-on knobs, 10 mm  $\varnothing$  with indicator



889502 - 11

Fig. 3. Pin-out of the most popular sockets found on television receivers and video recorders.



A complete kit of parts for the Video Recording Amplifier, which is designed in West Germany, is available from the designers' exclusive worldwide distributors (regrettably not in the USA and Canada):

**ELV**  
**B.P. 40**  
**F-57480 Sierck-les-Bains**  
**France**  
**Telephone +33 82.82.72.13**  
**Fax +33 82.83.81.80**

# HIGH-PRECISION DLF-BASED LOCKED FREQUENCY REFERENCE

by J. Bareford

This 10 MHz reference source for electronic clocks and laboratory equipment derives its stability of  $3 \times 10^{-8}$  from the powerful DeutschlandFunk (DLF) long-wave transmitter at 153 kHz.

The accuracy of a frequency standard locked onto the carrier of a transmitter is, in principle, only dependent on the accuracy at which the carrier is generated. In the case of a number of stations transmitting in the long-wave range (50 to 200 kHz), the stability of the carrier is derived from an atomic clock with extremely high precision. Examples of high-stability stations are DCF77 (see Ref. 1), Rugby MSF, Droitwich and DLF. Contrary to DCF77 and MSF, which are time-standard stations, DLF transmits an amplitude-modulated broadcast program. The stability of the daytime carrier at 153 kHz is  $5 \times 10^{-13}$  at a transmit power of 500 kW; that of the nighttime carrier is  $5 \times 10^{-12}$  at 250 kW. Fortunately, the transmitted signal is free from frequency and/or phase-modulated data services as implemented on DCF77 at 77.5 kHz.

The stability of the DLF carrier is better than almost any timebase used in electronic clocks and test and measurement equipment. The circuit described here is essentially a heterodyne receiver with an intermediate frequency of 3 kHz. The local oscillator and the intermediate frequency are both locked on to 10 MHz. In this set-up, a special type of phase-locked loop (PLL) circuit enables the ultra-stable 153 kHz carrier received from DLF to be used for controlling the frequency of a 10 MHz crystal oscillator.

## From 153 kHz to 10 MHz

The block diagram of Fig. 1 answers the question of how 153 kHz can be 'related to' 10 MHz. The central block is the voltage-controlled crystal oscillator (VCXO), which generates the 10 MHz reference signal. Two consecutive buffers clean and shape this signal, which is then taken through a band-pass filter before being fed to the output socket. The output signal of the first buffer is multiplied by a factor 1.5 and subsequently divided by 100 to give a digital signal of 150 kHz.

The Type SO42P integrated circuit at the input of the circuit mixes the received 153 kHz signal from DLF with the

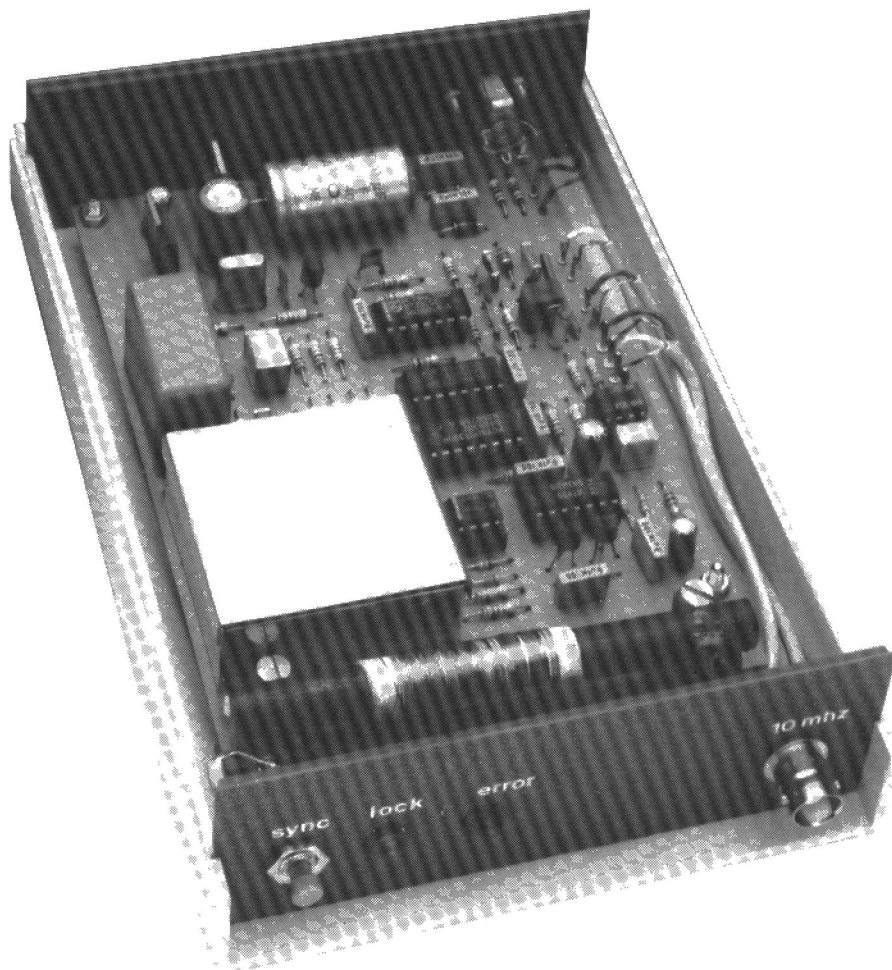
digital 150 kHz signal to give an intermediate frequency (IF) of 3 kHz, which is subsequently filtered in a band-pass section. The phase of this 3 kHz signal is compared with that of another 3 kHz signal, obtained by dividing the 150 kHz timebase signal by 50. The output of the phase comparator, which is actually a multiplier circuit, is passed through a loop filter with a cut-off frequency of 0.0003 Hz. The PLL error signal so obtained is used for controlling (i.e., correcting) the output frequency of the 10 MHz VCXO. In practice, the stability achieved with the prototype of the frequency standard, in the locked state, was measured as better than  $3 \times 10^{-8}$  within a period of 10 s.

The rather special configuration of the receiver ensures that short interference

on the received signal has virtually no effect on the stability of the output signal. For instance, an interfering pulse that results in an input frequency shift of, say, 1 kHz, results in an intermediate frequency shift that is 150 times smaller, causing negligible deviation of the 10 MHz ( $10 \times 10^6$  Hz) VCXO. For long-term interference, the VCXO should, of course, be controlled proportionally. The proposed structure of the receiver thus ensures that the 10 MHz output signal remains locked on to the received carrier from DLF, in spite of short-term interference, a feature that is not so simple to realize with a standard PLL.

## Circuit description

The circuit diagram of Fig. 2 shows how



the above concept has been worked out in practice.

The 10 MHz VCXO is essentially formed by transistor T<sub>3</sub>, quartz crystal X<sub>1</sub> and variable-capacitance diode D<sub>5</sub>. The emitter of T<sub>3</sub> carries the analogue 10 MHz signal, which is converted to a digital level by gate N<sub>1</sub>. Buffer gate N<sub>2</sub> feeds the digital 10 MHz signal to RLC low-pass filter C<sub>22</sub>-L<sub>5</sub>-C<sub>23</sub> at the output of the frequency standard. The output signal is a 10 MHz sinusoidal signal that requires buffering if long cables and/or relatively heavy loads are connected. The output is, however, capable of driving a single equipment without a buffer. The connecting cable should be short and co-axial.

Gate N<sub>1</sub> also drives a multiplier set up around N<sub>3</sub>, N<sub>4</sub> and tuned circuit L<sub>4</sub>-C<sub>39</sub>. The operation of the so-called *regenerative* frequency multiplier is basically as follows (also refer to the block diagram in Fig. 3). Pin 10 of N<sub>3</sub> is driven by the digital 10 MHz signal, and pin 9 by the signal developed across the tuned circuit. This resonates and sup-

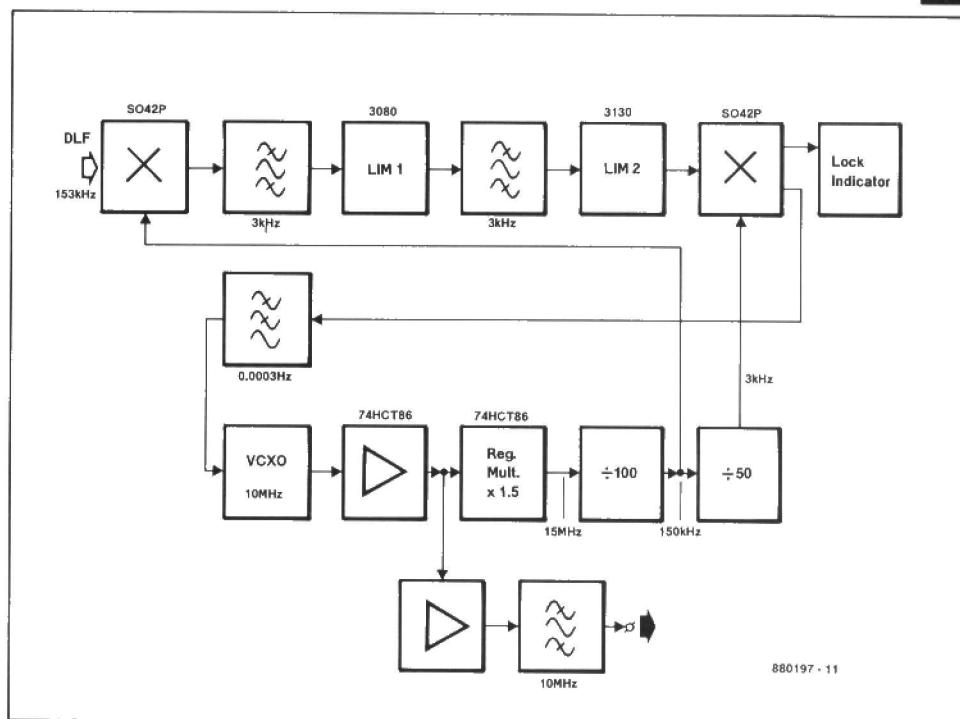


Fig. 1. Block diagram of the locked 10 MHz frequency reference.

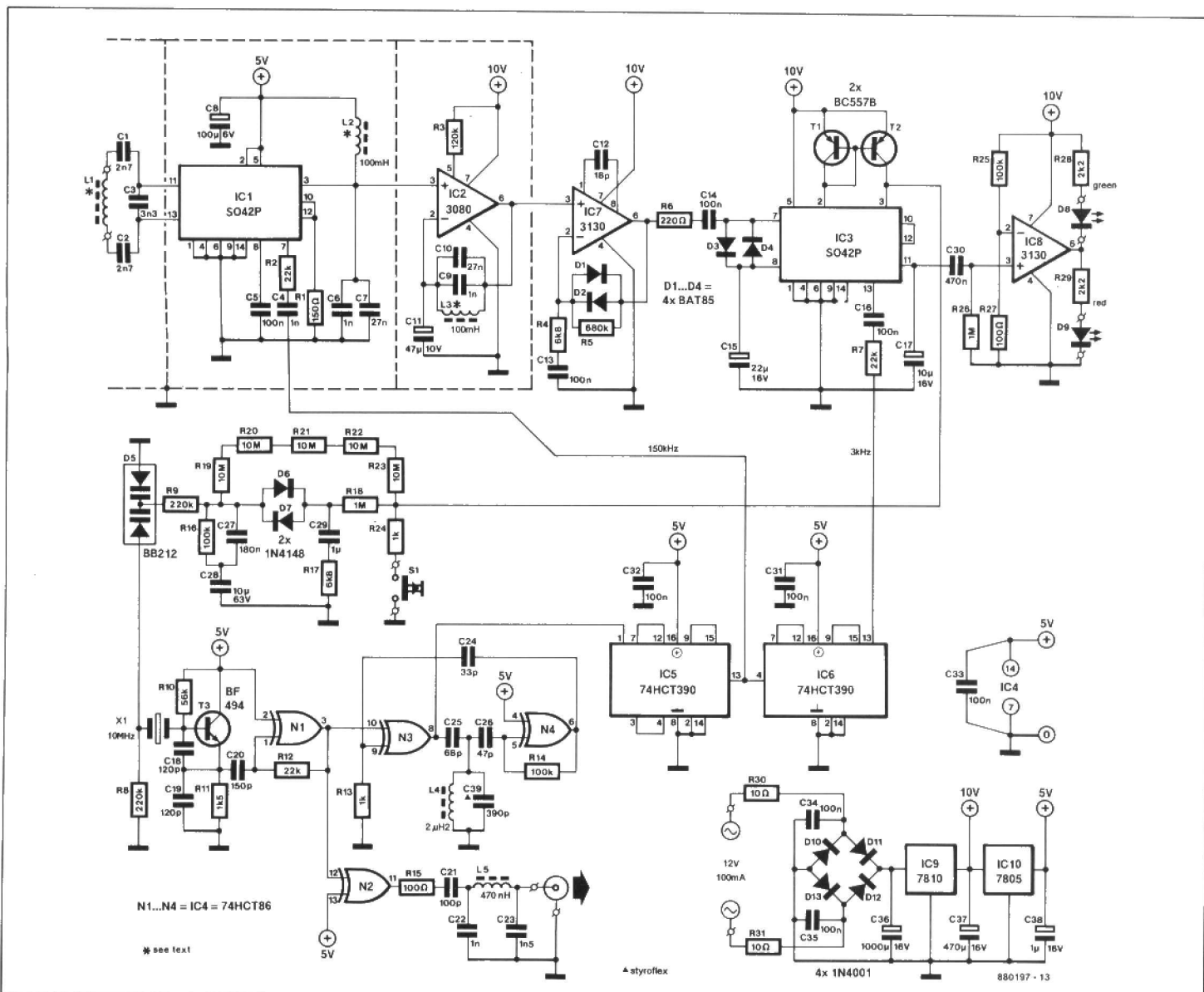


Fig. 2. Circuit diagram of the ultra-stable frequency reference, which derives its accuracy from the long-wave DLF broadcast transmitter at 153 kHz.

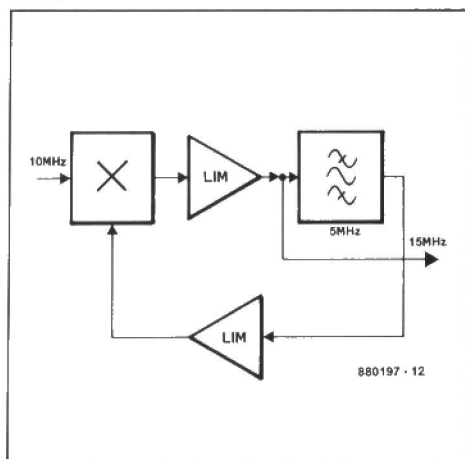


Fig. 3. Block diagram of one of the key circuits in the frequency reference: the regenerative frequency multiplier.

plies a 5 MHz signal which is digitized by gate  $N_4$ . The 10 MHz and 5 MHz signals are added by  $N_3$ , so that 15 MHz is available for clocking counter ICs. The R-C network in the multiplier,  $R_{13}$ - $C_{24}$ , and a polystyrene capacitor in the tuned circuit,  $C_{39}$ , ensure correct phase relationship of the signals applied to  $N_3$ , so that only the 15 MHz sum frequency is generated.

Counter ICs divide the 15 MHz signal by 100. The 150 kHz signal is applied to mixer IC<sub>1</sub>, and to a second counter, IC<sub>6</sub>, which is set up to divide by 50. The 3 kHz signal so obtained is fed to a second mixer, IC<sub>3</sub>.

The signal from DLF induces a voltage in tuned circuit  $L_1$ - $C_3$  connected to the balanced inputs of the Type SO42P mixer, IC<sub>1</sub>. The intermediate frequency obtained by mixing the received 153 kHz signal with that of the 150 kHz 'local oscillator' is filtered by IC<sub>2</sub> and a tuned circuit,  $L_3$ -( $C_9$ + $C_{10}$ ). After amplification and clipping by IC<sub>7</sub>, the 3 kHz signal is fed to multiplier IC<sub>3</sub>, another

Type SO42P. This stage compares the phase of the 3 kHz intermediate frequency with that of the 3 kHz timebase signal. The error signal produced by the comparator has a very low frequency, requiring a loop filter whose cut-off frequency is set to 0.0003 Hz ( $R_{19}$  through  $R_{23}$ ; 50 M $\Omega$ , and non-electrolytic capacitor  $C_{28}$ ; 10  $\mu$ F). The low-pass filter is only effective when the input frequencies of the phase comparator are almost equal, which results in small changes in the VCXO control voltage. With larger frequency differences, the control voltage has a much larger swing, so that  $D_6$  or  $D_7$  can conduct. When this happens, the response of the PLL becomes faster since the resistance in its R-C loop network is lowered from about 50 M $\Omega$  to 1 M $\Omega$ .

The VCXO control circuit enables the oscillator to be tuned correctly at only one side of the central frequency. If the voltage on  $C_{28}$  should rise beyond the normal tuning span of the VCXO, the PLL would have considerable difficulty returning to the locked state. Switch  $S_1$ , however, allows the VCXO frequency to be forced within the normal range, enabling the circuit to lock again. Fortunately,  $S_1$  will hardly ever need to be actuated once the PLL has locked on to the carrier from DLF.

A visual 'out-of-lock' indicator is set up around comparator IC<sub>8</sub>, and LEDs  $D_8$  and  $D_9$ . When the PLL is locked, there is no alternating voltage at pin 11 of IC<sub>3</sub>. This means that the voltage at pin 3 of IC<sub>8</sub> is more negative than that at pin 2, so that the output of the comparator is low and the green LED,  $D_8$ , lights. When the PLL is actively correcting the VCXO frequency, the alternating voltage at pin 11 of IC<sub>3</sub> causes the voltage at pin 3 of IC<sub>8</sub> to rise above that at pin 2. The comparator toggles and the red LED,  $D_9$ , lights to indicate that the 10 MHz output frequency is not stable. The indicator LEDs flash at the rate of the error signal if the circuit is out of lock. In the locked condition, it may occasionally happen that one of the LEDs lights briefly as a result of modulation or interference.

The frequency reference is powered by conventional 5 V and 10 V regulated supplies. Networks  $R_{30}$ - $C_{34}$  and  $R_{31}$ - $C_{35}$  suppress mains-borne noise.

## Construction

Figure 4 shows the track layout and component mounting plan of the PCB designed for the frequency reference. For optimum stability of the reference, tin-plate screens must be fitted on to the board. For the location of these screens, see the photograph of the prototype in Fig. 5.

Do not replace the 10  $\mu$ F solid capacitor

## Parts list

### Resistors ( $\pm 5\%$ ):

$R_1 = 150R$   
 $R_2, R_7, R_{12} = 22K$   
 $R_3 = 120K$   
 $R_4, R_{17} = 6K8$   
 $R_5 = 680K$   
 $R_6 = 220R$   
 $R_8, R_9 = 220K$   
 $R_{10} = 56K$   
 $R_{11} = 1K5$   
 $R_{13}, R_{24} = 1K0$   
 $R_{14}, R_{16}, R_{25} = 100K$   
 $R_{15}, R_{27} = 100R$   
 $R_{18}, R_{26} = 1M0$   
 $R_{19} \dots R_{23}$  incl. = 10M  
 $R_{28}, R_{29} = 2K2$   
 $R_{30}, R_{31} = 10R$

### Capacitors:

$C_1, C_2 = 2n7$   
 $C_3 = 3n3$   
 $C_4, C_6, C_9, C_{22} = 1n0$   
 $C_5, C_{13}, C_{14}, C_{16}, C_{31} \dots C_{35}$  incl. = 100n  
 $C_7, C_{10} = 27n$   
 $C_8 = 100\mu$ ; 6 V; radial  
 $C_{11} = 47\mu$ ; 10 V; radial  
 $C_{12} = 18p$   
 $C_{15} = 22\mu$ ; 16 V; radial  
 $C_{17} = 10\mu$ ; 16 V; radial  
 $C_{18}, C_{19} = 120p$  ceramic NPO  
 $C_{20} = 150p$   
 $C_{21} = 100p$   
 $C_{23} = 1n5$   
 $C_{24} = 33p$   
 $C_{25} = 68p$   
 $C_{26} = 47p$   
 $C_{27} = 180n$   
 $C_{28} = 10\mu$ ; 63 V MKT (do not use an electrolytic type!)  
 $C_{29} = 1\mu0$ ; MKT  
 $C_{30} = 470n$   
 $C_{36} = 1000\mu$ ; 25 V  
 $C_{37} = 470\mu$ ; 16 V; radial  
 $C_{38} = 1\mu0$ ; 16 V; radial  
 $C_{39} = 390p$  polystyrene ('styroflex')

### Inductors:

$L_1$  = home-made inductor, wound on 10 cm long, 10 mm dia. ferrite rod; see text.  
 $L_2, L_3$  = 100mH radial inductor with ferrite encapsulation; Toko Type 181LY-104 (Circuit stock no. 34-10402).  
 $L_4 = 2\mu H$  axial inductor.  
 $L_5 = 470nH$  (0.47 $\mu$ H) axial inductor.

### Semiconductors: $D_1 \dots D_4$ incl. = BAT85

(Cricklewood)  
 $D_5$  = BB212 (C-I Electronics)  
 $D_6, D_7$  = 1N4148  
 $D_8$  = green LED  
 $D_9$  = red LED  
 $D_{10} \dots D_{13}$  incl. = 1N4001

$T_1, T_2$  = BC557B

$T_3$  = BF494

IC<sub>1</sub>; IC<sub>3</sub> = SO42P (Universal Semiconductor Devices; Cricklewood)

IC<sub>2</sub> = CA3080

IC<sub>4</sub> = 74HCT86

IC<sub>5</sub>; IC<sub>6</sub> = 74HCT390

IC<sub>7</sub>; IC<sub>8</sub> = CA3130

IC<sub>9</sub> = 7810

IC<sub>10</sub> = 78L05

### Miscellaneous:

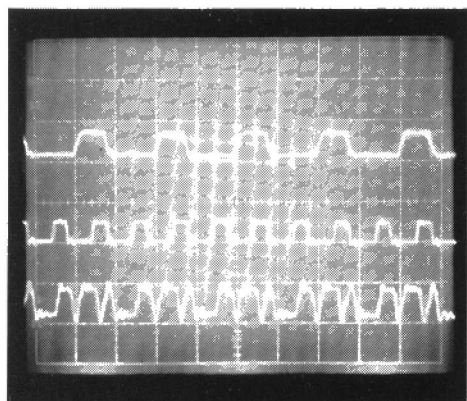
$S_1$  = push-to-make button

$X_1$  = 10 MHz quartz crystal; 30 pF parallel resonance.

Ferrite rod: length approx. 10 cm; diameter 10 mm.

Mains transformer or mains adapter 12 V; 100 mA.

PCB Type 880197 (not available through the Readers Services).



Oscilloscope photograph to illustrate the operation of the regenerative frequency multiplier. Upper trace: 5 MHz input; middle trace: 10 MHz input; lower trace: 15 MHz 'regenerated' output frequency. Note the phase relationship between the 5 and 10 MHz input signals.

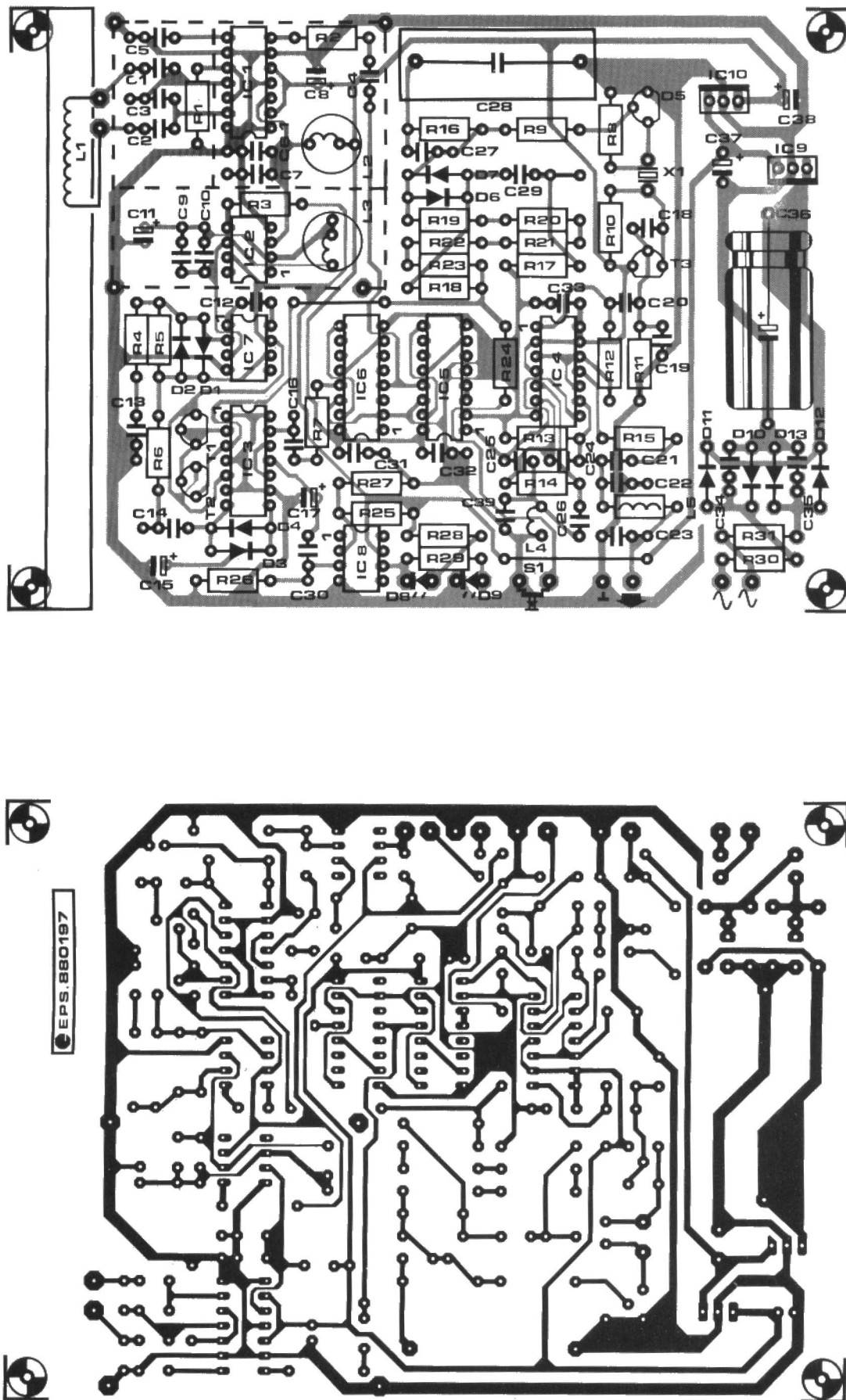


Fig. 4. Track layout and component mounting plan of the printed-circuit board designed for the frequency reference.

in position C<sub>28</sub> with an electrolytic type. The quality factor of inductors L<sub>2</sub> and L<sub>3</sub> is critical and governs the use of ready-made, ferrite-encapsulated, 100 mH types from Toko.

The aerial coil is wound on a paper, paxolin or thin cardboard former of an internal diameter that enables it to be slid on to a 10 cm long ferrite rod of 10 mm diameter. The inductor is made from 150 closewound turns of 0.2 mm (SWG34) enamelled copper wire. The aerial circuit is tuned to 153 kHz by sliding the former over the rod until reception is optimum. The ferrite rod is secured on to the PCB with the aid of two plastic cable ties. The wire ends of the inductor are twisted and then connected to the PCB.

When high noise levels are anticipated in the long-wave band, it is recommended to make the aerial more directive by fitting it in a round aluminium or tin-plate holder as shown in Fig. 6. To prevent this short-circuiting the RF signal, it should have a lengthwise gap below the ferrite rod. Also note that the holder must not be closed at the ends.

## Testing and setting up

The locked frequency reference has only one adjustment: the aerial. Slide the former across the rod until a point is found where an oscilloscope connected to pin 6 of IC<sub>2</sub> indicates maximum amplitude of the 3 kHz intermediate frequency. If necessary, rotate the board with the ferrite rod horizontally to maximize the received signal. The minimum amplitude for correct operation of the PLL is about 600 mV<sub>pp</sub> at pin 3 of IC<sub>2</sub>. When an oscilloscope is not available, the aerial may be aligned until a clean 3 kHz sine-wave is heard in a high-impedance earpiece or headset. Depending on the tolerances of the capacitors used in the tuned circuit, it may be necessary to increase or decrease the number of turns by 10 or so. The aerial works best with the former about central on the ferrite rod.

The 10 MHz output on the printed circuit board is connected to a BNC socket on the front panel of the enclosure. Since the ferrite aerial is mounted on to the board, the enclosure should be an ABS rather than a metal type.

After powering up, the red light is most likely to light. After a short delay, both the green and the red LED flash rhythmically for a couple of seconds. Then, if everything is in order, the red LED goes out and the green one lights to indicate good reception. The output of the frequency reference then supplies an ultra-stable 10 MHz signal.

If reception is poor or marginal, as indicated by intermittent lighting of both LEDs or the red LED alone, rotate the

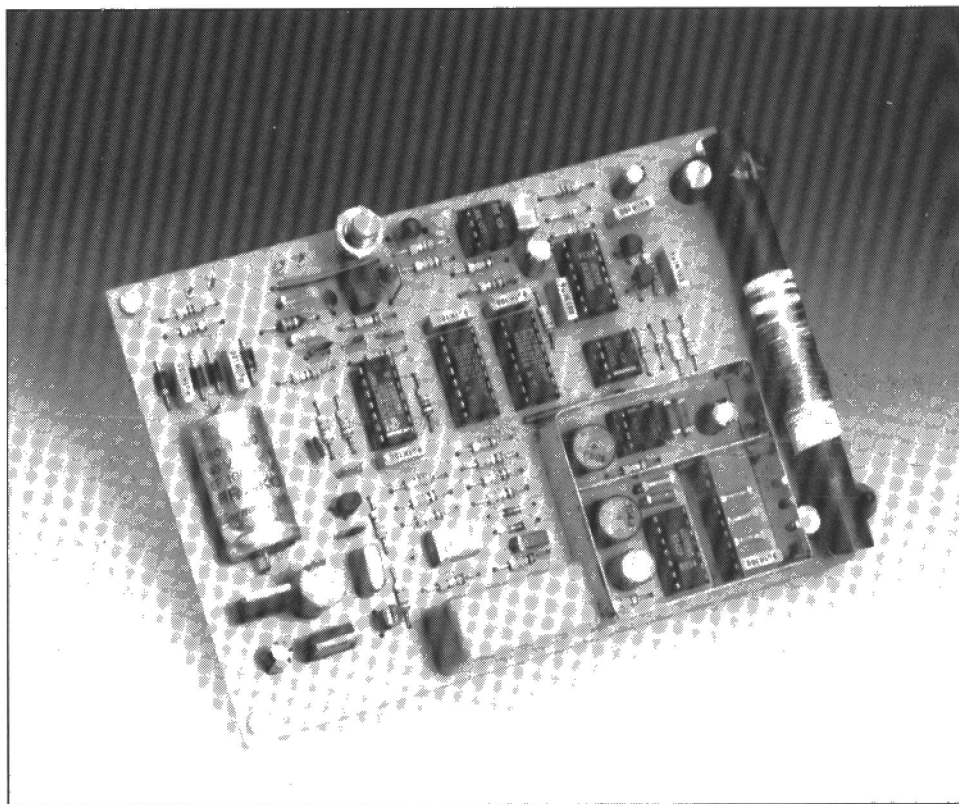


Fig. 5. Prototype board with aerial coil and screening installed.

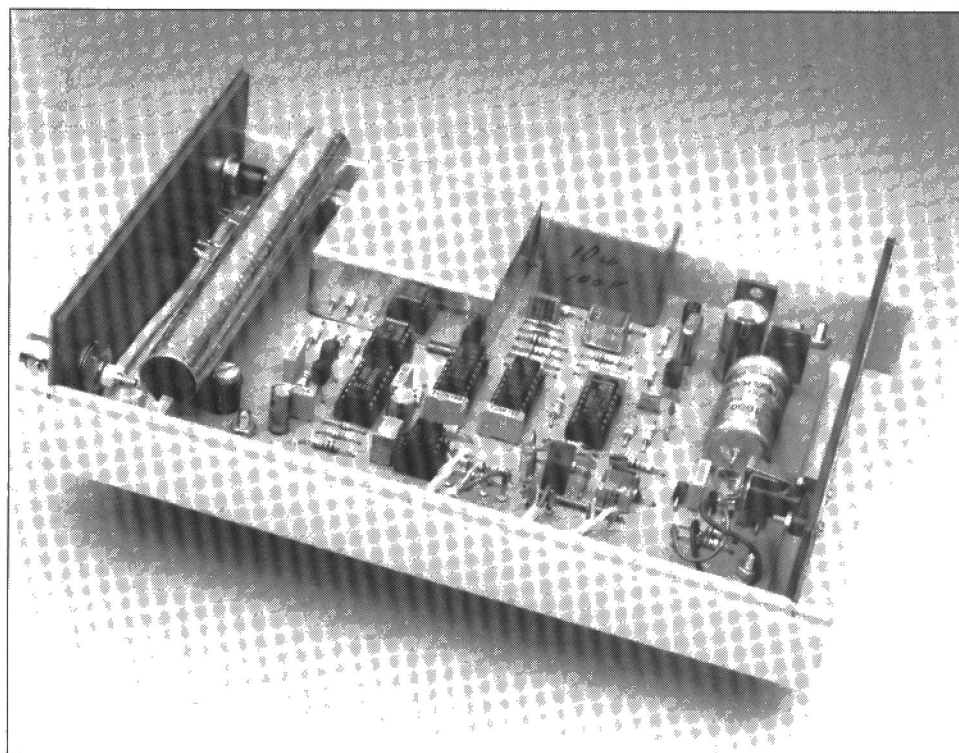


Fig. 6. The aerial can be given extra directivity with the aid of this construction.

unit so as to direct the aerial towards DLF.

standard. *Elektor Electronics* January 1988.

## Reference:

1. DCF77 receiver and locked frequency

# INTERMEDIATE PROJECT

**A series of projects for the not-so-experienced constructor. Although each article will describe in detail the operation, use, construction and, where relevant, the underlying theory of the project, constructors will, none the less, require an elementary understanding and knowledge of electronic engineering. Each project in the series will be based on inexpensive and commonly available components.**

## 3a. Function Generator

by J. Bareford

No one seriously involved in electronics design and construction, or the study of these subjects, can do without a function generator, which is essentially a signal source that supplies a number of waveforms of variable frequency and amplitude. This month's instalment in the series on intermediate project deals with a triangular/rectangular wave generator, which is the first of three modules that together form a test instrument with an excellent price-performance ratio.



One of the advantages of a modular design is that the user is in a position to decide on the configuration that is most appropriate to his purpose. The function generator described here is such a modular design, whose central part, the triangular/rectangular wave generator, is described here. Optional add-on modules, such as a sine-wave converter and an output amplifier, will be discussed in future instalments.

### Applications

A function generator is almost invariably used in conjunction with an oscilloscope to check the operation of a wide variety of amplifiers. Although the rectangular signal (Fig. 1a) is used mainly for driving digital circuits, it may also be used for a quick check on the

bandwidth of an audio amplifier. As a rule of thumb, an amplifier has a bandwidth smaller than 20 kHz if the corners of a 1 kHz rectangular signal applied to it appear rounded on the oscilloscope that measures the amplifier's output signal. Similarly, if the 'horizontal' parts of the rectangular wave look like a sine-wave, the amplifier is likely to suffer from stability problems.

The actual bandwidth of the amplifier under test can be gauged with the aid of the sinusoidal output signal of the function generator. Since this supplies a virtually constant output level, the amplifier's output signal between, say, 50 Hz and 20 kHz, should also remain constant, provided, of course, the tone controls are disabled. The so-called -3 dB bandwidth of the amplifier is easily measured by first defining the output

amplitude across the nominal load (loudspeaker) at 1 kHz as the reference level, and then tuning the sine-wave generator until the low and high frequencies are found at which the amplifier's output signal equals 70% of the reference level. These frequencies correspond to the so-called -3 dB (*half power*) points. Finally, the triangular wave (Fig. 1b) may be used for tracing the cause(s) of so-called *cross-over* distortion in an amplifier with a complementary (push-pull) output stage. Cross-over distortion is noticed on the oscilloscope as rounding or even discontinuity of the triangular signal near the 0 V level. The effect is most prominent at low input amplitudes, and is usually remedied by increasing the quiescent current in the power output stage.

The above examples are all related to testing audio amplifiers. The function generator is, however, also indispensable for adjusting filters as used in, for instance, telex and facsimile converters, and some types of radio and TV circuits. In any case, the unit is likely to be the first equipment switched on after applying power for the first time to a newly built amplifier.

### Modular and what it means

The block diagram of the function generator is given in Fig. 2. As already noted, the final configuration is not fixed in any way. The blocks marked '1' are, however, essential in all cases, since they provide the signals used by other, optional, modules.

The three available waveforms may be fed to an amplifier via a waveform selection switch and an amplitude control. The amplifier does not magnify its input voltage, but serves as a buffer that enables low-impedance loads to be driven. The numbers with the blocks in the diagram indicate the instalments that discuss the operation and construction of the relevant module.

### Triangular and rectangular waveforms

As indicated in the block diagram, the triangular and rectangular wave generators are combined in a single circuit. In the present design, this is because the triangle generator can not work by itself: it requires the particular type of feedback provided by the rectangular wave generator.

The circuit diagram of Fig. 3 shows the triangular wave generator to the left and the rectangular wave converter to the right. Readers familiar with opamp circuits will recognize the first as an integrator, and the second as a comparator with hysteresis. Together, these circuits are capable of supplying two types of alternating voltage.

### Integrator

An integrator is the 'electronic-circuit' equivalent of the mathematical operation that divides an input quantity (signal) into small time intervals, and adds the levels calculated (measured) in these intervals. Assuming that a direct voltage of 1 V is applied to an integrator with a time interval of 1 s, a staircase-like output signal is generated whose amplitude rises by 1 V every second. In a real integrator, the time interval is made so short as to produce a virtually continuously rising output level. To prevent the output signal almost instantly reaching the supply level, the integrator is modified to measure a small part of the input signal, rather than the full am-

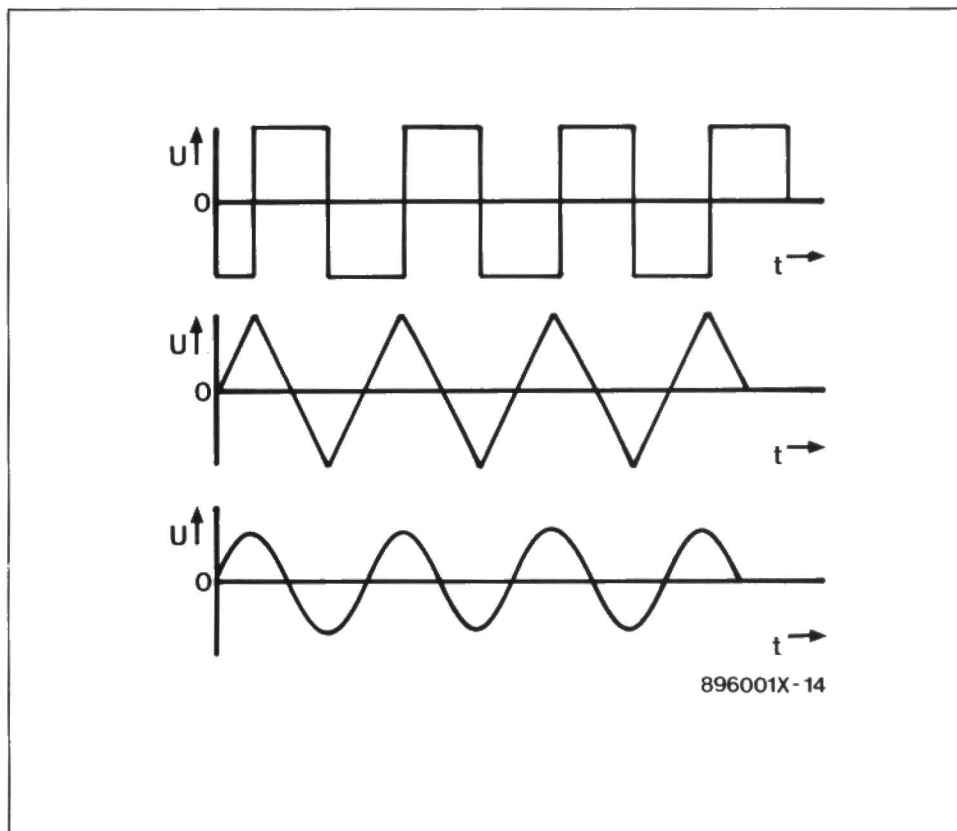


Fig. 1. The alternating voltages supplied by a function generator can have different shapes and are, therefore, called *waveforms*. The waveforms supplied by the function generator described here and in forthcoming articles are 'rectangular' (a), triangular/sawtooth (b), and sinusoidal (c).

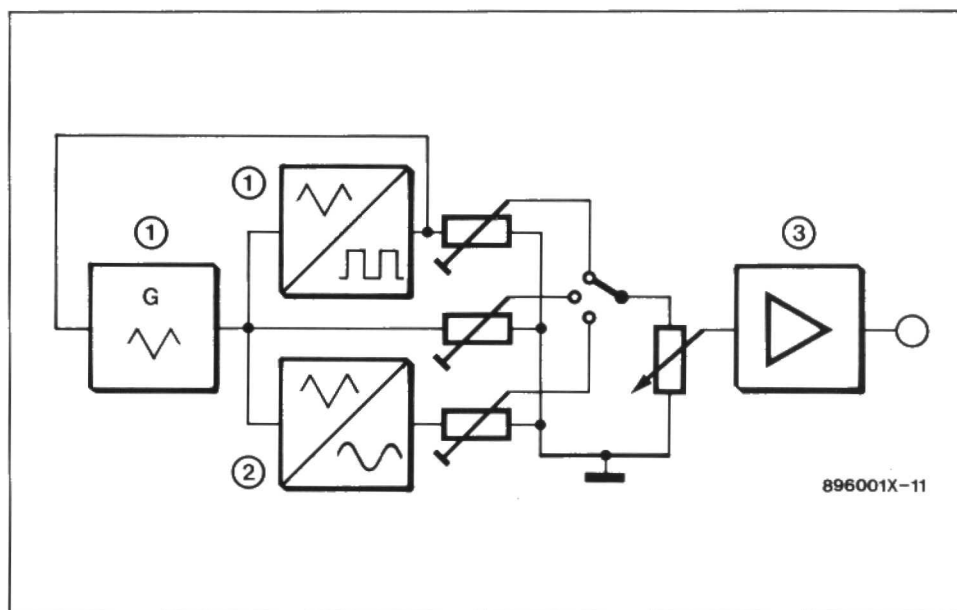


Fig. 2. The complete function generator is composed of four functional blocks.

plitude. In this example, the step size may be reduced to, say,  $1 \mu\text{V}$ . Summarizing the above, an integrator converts a direct voltage into a linearly increasing or decreasing voltage, which may be drawn as a straight line whose slope (or *gradient*) is determined by the magnitude of the input voltage and the predefined step reduction factor. The output voltage decreases or increases with a negative or positive input voltage respectively.

The basic electronic integrator is shown in Fig. 4. The opamp is assumed ideal, so that the input currents are nought, as is the voltage difference between the + and - input, but only if the output voltage is lower than the supply voltage. Since the + input of the opamp is connected to ground, it follows that the - input is also at 0 V (*virtual ground*). Hence, The voltage on  $R_1$  equals the input voltage,  $U_i$ . Assuming that this is a direct voltage,  $R_1$  carries a constant cur-

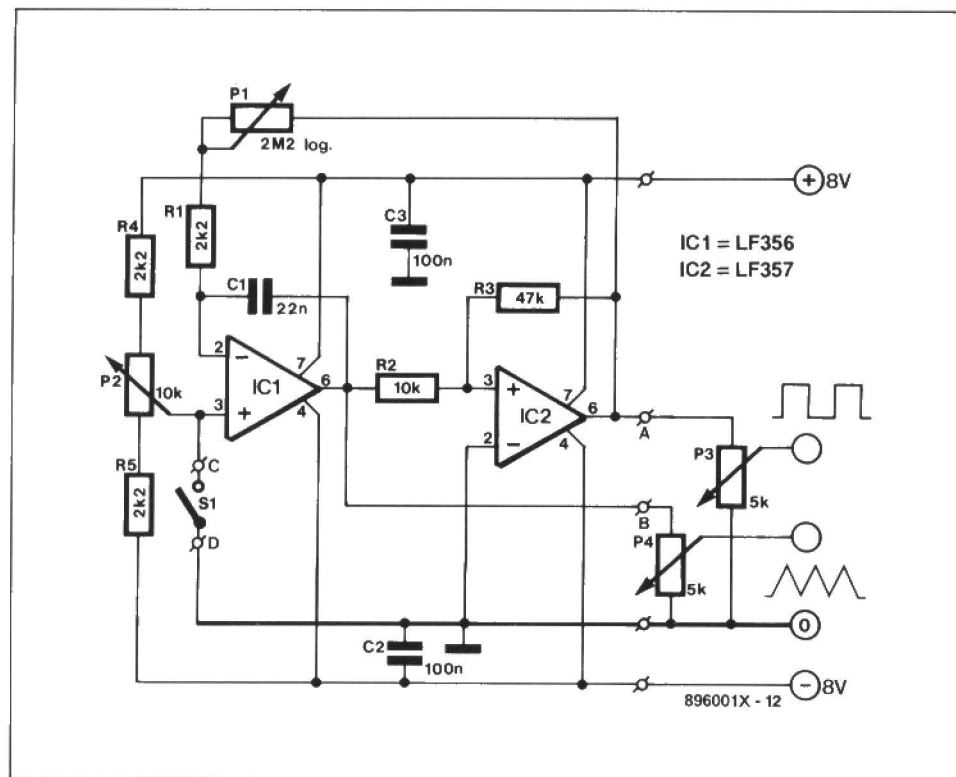


Fig. 3. Circuit diagram of the rectangular/triangular wave generator, the first building block in the low-cost function generator.

rent,  $I$ :

$$I = U/R = U_i/R_1$$

Since the input current of the opamp is nought, current  $I$  must flow through capacitor  $C$ , which is charged as a result. The charge,  $Q$ , built up in  $C$  is the product of the magnitude of  $I$  and the time,  $t$ , lapsed since the start of the charge cycle:

$$Q = It$$

Substituting  $I$  with equation (1) gives:

$$Q = (U_i/R_1)t \quad (2)$$

The voltage on  $C_1$ ,  $U_c$ , rises according to:

$$U_c = Q/C_1 \quad (3)$$

Entering equation (2) in (3) gives

$$U_c = (U_i/R_1)t/C_1$$

$$U_c = U_i/(R_1 C_1)t$$

The ratio  $U_i/(R_1 C_1)$  remains constant, and  $U_c$  rises linearly with time, as long as  $R_1$  and  $C_1$  remain unchanged and the input signal is a direct voltage. So far, the operation of the basic circuit corresponds to that of the ideal integrator. There is, however, one point to note: the voltage on  $C_1$  is defined with respect to the virtual ground level, which means that a positive input voltage produces a negative output voltage, and the other way around. The integrator is an inverter!

As already shown in Fig. 3, the output signal of the rectangular wave generator is fed back to the input of the integrator, so that this is not driven with a pure direct voltage, but one whose polarity toggles as a function of time. The resulting output signal at the output of the integrator is, therefore, a triangular waveform, which is what we were after in the first place.

### Comparator with hysteresis

The fundamental characteristic of a comparator is its ability to determine which of two applied voltages is the larger, and, depending on the result, pull its output to a level virtually equal to the

positive or negative supply voltage. For the comparator in the function generator, redrawn in Fig. 5., this means that the output voltage becomes  $+8\text{ V}$  if the potential at the  $+$  input rises just above  $0\text{ V}$ , and  $-8\text{ V}$  when it drops just below  $0\text{ V}$  (remember that the  $-170-$  input is at  $0\text{ V}$  because it is tied to ground). However, resistors  $R_2$  and  $R_3$  give the circuit a certain hysteresis, so that the comparator does not toggle if the input voltage is just above or below  $0\text{ V}$ . The real toggle potential can be calculated as shown below.

Assuming the output to be at  $+8\text{ V}$  and the input at  $0\text{ V}$ , the voltage on potential divider  $R_2$ - $R_3$  is  $8\text{ V}$ . The resulting voltage at the  $+$  input of the opamp,  $U_+$ , is calculated as

$$U_+ = R_1/(R_1 + R_2) \times 8\text{ V}$$

$$U_+ = 0.175 \times 8\text{ V} = 1.4\text{ V}$$

Since the voltage at the  $+$  input is higher than  $0\text{ V}$ , the output voltage remains at  $+8\text{ V}$ . Note that, in this type of circuit, the input of the opamp is not a virtual ground point, since the output voltage has risen to the supply level. The comparator does not toggle until the voltage at the  $+$  input is  $0\text{ V}$ , which means that the voltage on  $R_3$  is  $8\text{ V}$ , and the input voltage is negative. The negative potential that forms the toggle point is fairly simple to calculate. Since the voltage on  $R_3$  is  $8\text{ V}$ , the resistor carries  $8\text{ V}/47\text{ k}\Omega = 0.17\text{ mA}$ . This current also flows through  $10\text{ k}\Omega$  resistor  $R_2$  (the opamp input current is nought), and causes a voltage drop of  $1.7\text{ V}$ . Hence, the input voltage must be more negative than  $-1.7\text{ V}$  to enable the comparator to toggle to  $-8\text{ V}$ .

This is not the whole story, however, since nothing happens when the input voltage rises just above  $-1.7\text{ V}$ . This is because the output voltage has gone negative, so that a positive input level is required to enable the comparator to revert to the initial state. This level is calculated in a similar manner as the

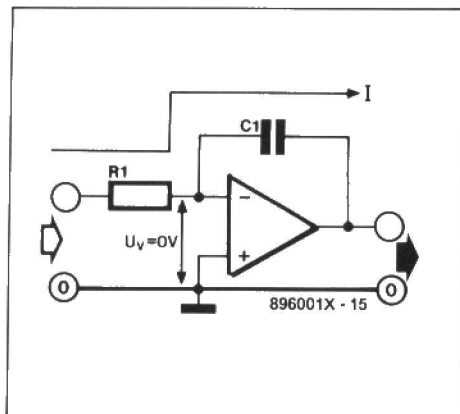


Fig. 4. Basic integrator that converts the input voltage into a charge current for capacitor  $C_1$ .

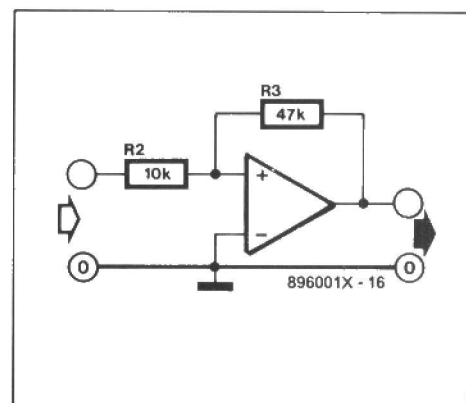
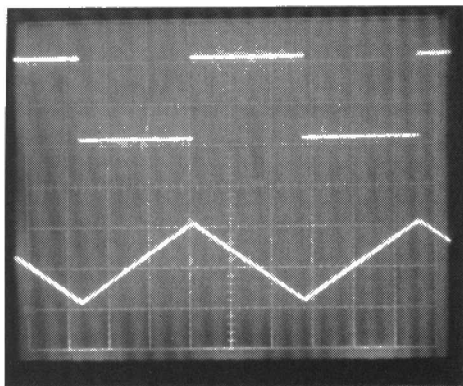


Fig. 5. Basic comparator with hysteresis. The resistors define toggle levels at  $+1.7\text{ V}$  and  $-1.7\text{ V}$  for increasing and decreasing input voltages respectively.

a



b

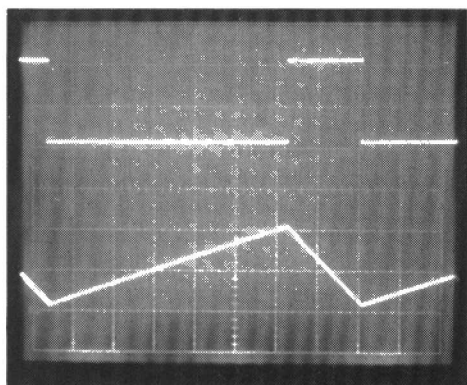


Fig. 6. The symmetrical waveform (a) may be made asymmetrical (b) by applying a bias voltage to the + input of IC<sub>1</sub>.

negative level, and results in +1.7 V.

### Oscillation: why?

The circuit description is not complete without explaining why the combination of the integrator and the comparator is a self-oscillating circuit.

Assuming that the output of the comparator switches from  $-8\text{ V}$  to  $+8\text{ V}$ ,  $R_1$  and  $P_1$  pass a current that first discharges  $C_1$ , and then gives it a positive charge (assume that the circuit has been in operation for some time, which means that  $C_1$  has a negative charge). The output voltage of the integrator decreases at a speed determined by the charge current, i.e., the setting of  $P_1$ . When the integrator's output voltage becomes smaller than  $-1.7\text{ V}$ , the comparator toggles and inverts the potential at the input of the integrator. The current through  $C_1$  reverses, resulting in a slowly increasing voltage at pin 6 of IC<sub>1</sub>, until  $+1.7\text{ V}$  is reached. The comparator then toggles again, and the process is repeated.

The above shows that the circuit oscillates by virtue of the hysteresis of the comparator, and the fact that some time is needed for the charging of  $C_1$ . The oscillation frequency is determined by the rate of charge of  $C_1$ , or, in other words, the setting of  $P_1$ .

### Asymmetrical voltage: sawtooth and duty factor control

In the practical circuit, switch  $S_1$  takes the + input of the integrator to ground (as in Fig. 4) or to a potential at the wiper of potentiometer  $P_2$ , which provides a control span of  $+5.5\text{ V}$  to  $-5.5\text{ V}$ .

With  $P_2$  set to  $+5.5\text{ V}$ , the - input of the opamp is also at  $+5.5\text{ V}$  (there is no voltage difference between the + and - input). This means that the voltage across  $R_1$  is not always  $+8\text{ V}$  or  $-8\text{ V}$ , but  $+2.5\text{ V}$  with the comparator output at  $+8\text{ V}$ , and  $-14.5\text{ V}$  with the output at  $-8\text{ V}$ . Therefore,  $R_1$  passes a larger current during the negative excursion of the comparator output voltage than during the positive excursion. The charge time

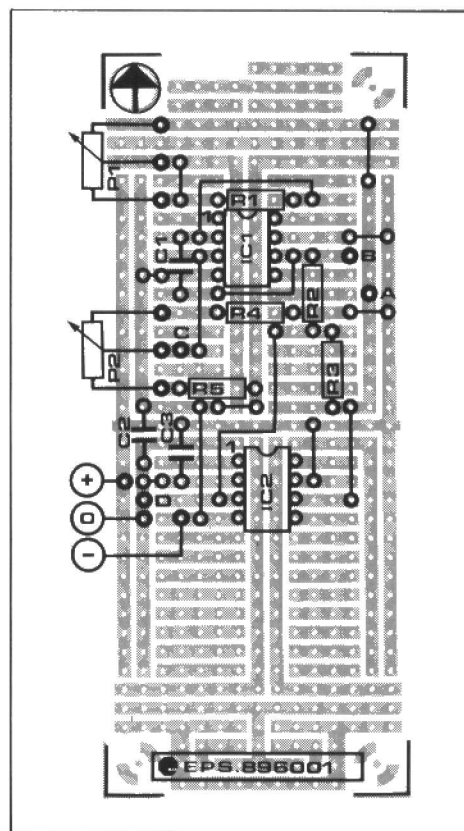


Fig. 7. Component mounting plan on board UPBS-1.

#### Parts list

##### Resistors ( $\pm 5\%$ ):

$R_1; R_4; R_5 = 2\text{K}2$   
 $R_2 = 10\text{K}$   
 $R_3 = 47\text{K}$   
 $P_1 = 2\text{M}2$  logarithmic potentiometer  
 $P_2 = 10\text{K}$  linear potentiometer  
 $P_3; P_4 = 5\text{K}$  linear potentiometer

##### Capacitors:

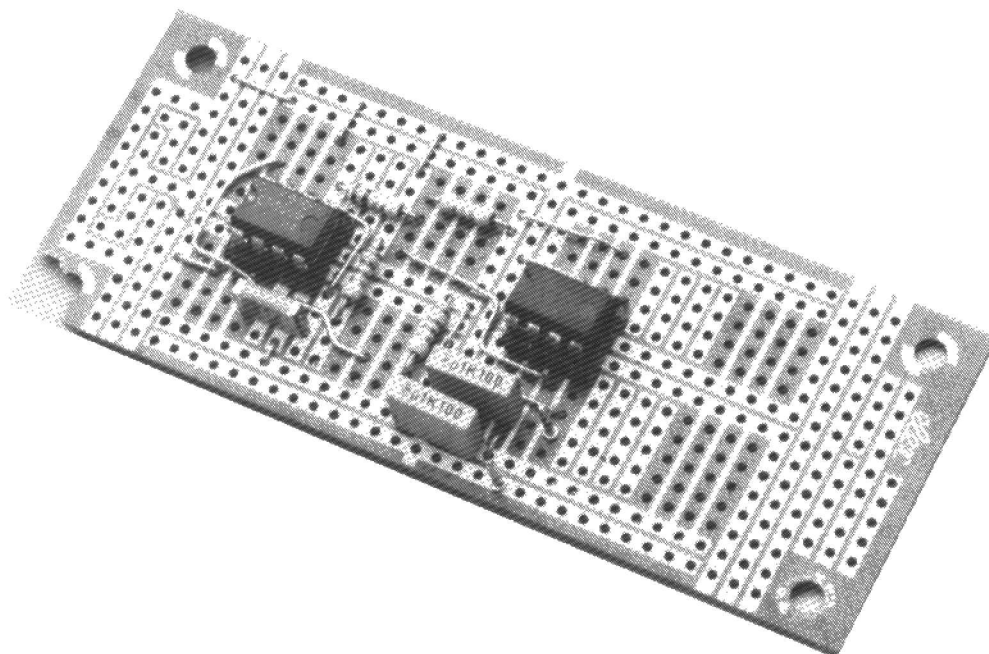
$C_1 = 22\text{n}$   
 $C_2; C_3 = 100\text{n}$

##### Semiconductors:

$\text{IC}_1 = \text{LF}356$   
 $\text{IC}_2 = \text{LF}357$

##### Miscellaneous:

$S_1 =$  miniature on/off switch.  
 Symmetrical  $\pm 8\text{ V}$  power supply or two  $9\text{ V}$  PP3 batteries.  
 2 BNC or phono sockets.  
 PCB Type UPBS-1 (see Readers Services page).



of  $C_1$  is inversely proportional to this current, so that a negative charge is built up faster than a positive one, resulting in a sawtooth waveform since the rising and falling slope have a different gradient. The shape of the rectangular waveform is also altered because one toggle point is reached sooner than the other. As a result, the duty factor of the signal is increased because the 'low' parts become shorter than the 'high' parts (see Fig. 6.)

The inverse applies when  $P_2$  is set to provide  $-5.5\text{ V}$  to the  $+$  input of  $IC_1$ . In that case,  $C_1$  is charged to a positive level more rapidly than to a negative level, so that the rising slope of waveform becomes longer than the falling slope. In the case of the rectangular waveform, the duty factor is reduced accordingly. The main disadvantage of this simple type of waveform symmetry control is that it lowers the output frequency to some extent.

## Building the first module

After this thorough discussion of the operation of the triangular and rectangular waveform generator, it is time to put the theory to the test.

A suggested construction on Universal Prototyping Board Size-1 (UPBS-1) is shown in Fig. 7. When completed, this board may be fitted into an enclosure as shown in the introductory photograph. A suggestion for the layout of the front-panel is given in Fig. 8. Alternatively, the mounting of the board may be postponed to a later stage when the other modules of the function generator are available. As already stated, these will be described in forthcoming instalments in this series of articles. ■

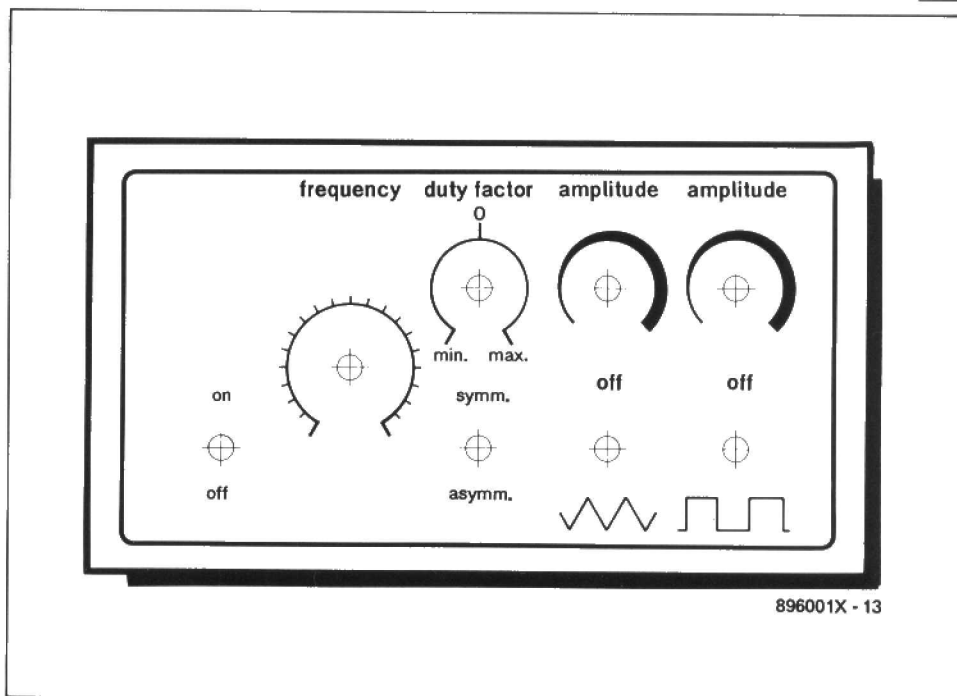
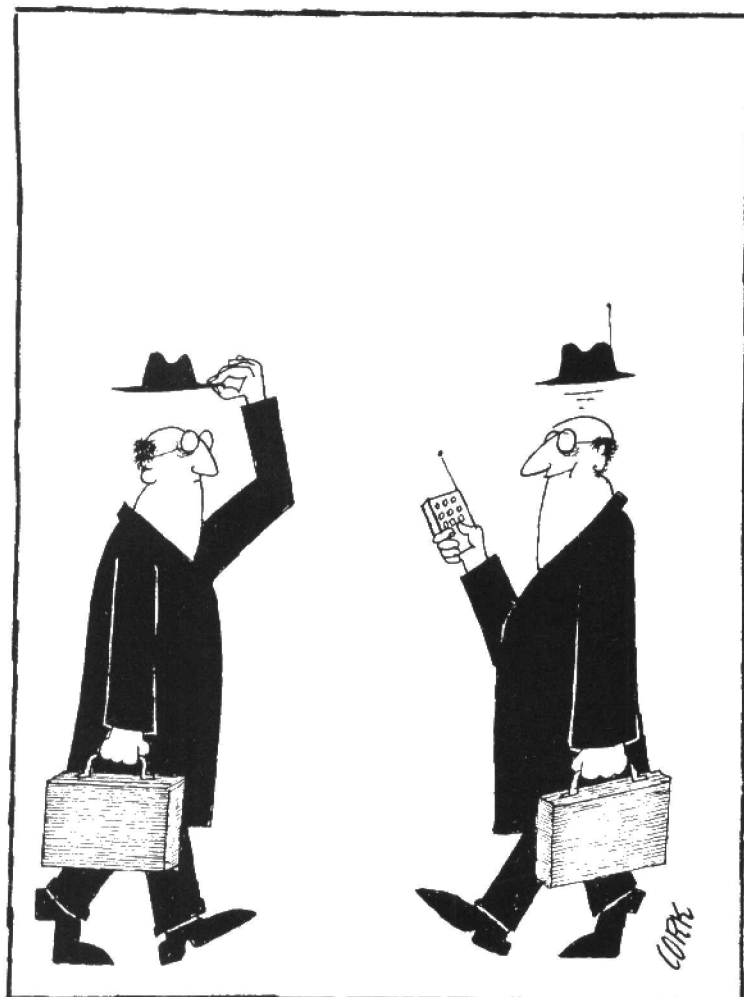


Fig. 8. Suggested front-panel layout.



## NEW BOOKS

### Catalogues and brochures

#### J.A. Crew & Co. Catalogue

The latest catalogue (number 25) from J.A. Crew & Co offers, in 71 pages, a wide variety of materials, tools and components, many not easily found in other catalogues. Get your copy now from J.A. Crew & Co. • Spinney Lane • Aspley Guise • MILTON KEYNES MK17 8JT • Telephone (0908) 583252.

#### VME Backplanes Brochure

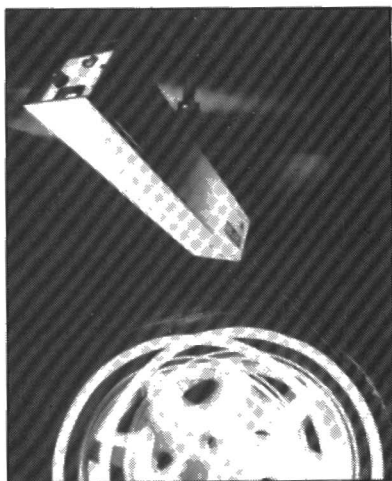
A full-colour eight-page brochure covering a comprehensive range of VMEbus backplanes that carry certificates of conformity from VME Laboratories USA is available from System Kontakt. It details in an easy-to-read format the wide range of slot lengths, on 3TE to 6TE pitches, available. Highlighted in the brochure are 16-bit and 32-bit systems, power supply arrangements, terminations, bus extensions, and dimensional and pin-assignment information.

For further information contact Derek Whittington at System Kontakt UK • 7 The Paddock • Hambridge Road • NEWBURY RG14 5TQ • Telephone (0635) 34723.

### SMT low-profile capacitor

The latest addition to Vitramon's wide range of monolithic ceramic capacitors for surface-mount technology is the v1 1210. This low-profile capacitor is designed specifically for decoupling memories and logic circuits and fits in the space beneath a plastic leaded chip carrier.

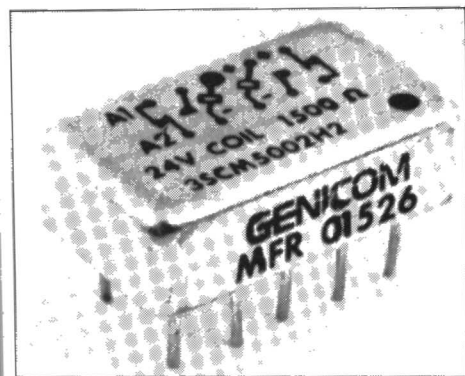
**Vitramon Ltd • Wycombe Lane • WOOBURN GREEN HP10 0HH.**



Brüel & Kjær has introduced a laser transducer that provides a rugged, affordable solution to the problem of making vibration measurements without physically contacting the vibrating surface. Brüel & Kjær • 92 Uxbridge Road • HARROW HA3 6BZ • Telephone 01-954 2366.

### Magnetically-latched relay

Genicom's Type 3SCM bistable relay, available from Granville Components is designed for applications requiring quality performance at minimum power



levels. The relay's magnetic system requires a pulse of only 0.5 mJ for 2 ms to latch up, which provides a memory function and is particularly beneficial when power drain is a problem.

**Granville Components Ltd • Granville Court • The Mall • FAVERSHAM ME13 8JL • Telephone (0795) 539481.**

### Control 80

Requiring a +5 V supply, the Z80 CPU operates at 4 MHz (6 MHz version also

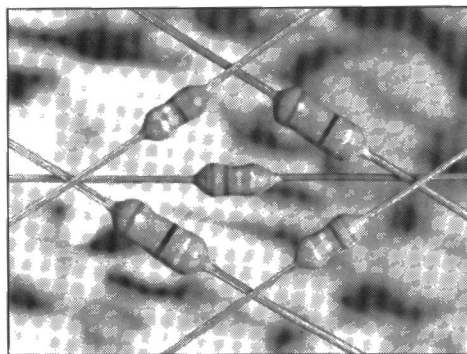
available) and provides the designer with a tested microsystem, saving him valuable time on faultfinding. Two 28-pin sockets provide space for up to 16 kbyte of EPROM and a further socket houses 8 kbyte of STATIC RAM which is supplied with the unit. EPROMs are not included.

A Z80A P10 provides the I/O with 16 signal lines and allows easy interfacing to displays, keyboards, relays, and so on. **J.P. Designs • The Old School • Prickwillow • ELY CB7 4UN • Telephone (035 388) 325/455.**

### Miniature RF inductors

Two ranges of miniature axial RF inductors available in values from 0.1  $\mu$ H to 1000  $\mu$ H have been introduced by Magna Frequency Management.

The EC-24 and EC-36 devices have low d.c. resistance (0.075-30  $\Omega$  for the EC-24 and 0.21-14  $\Omega$  for the EC-36) so that they may be used in applications that



previously would have required physically larger components.

**Magna Frequency Management • The Grip Industrial Estate • Hadstock Road • Linton • CAMBRIDGE CB1 6NR • Telephone (0223) 892015.**

### Tantalum axial capacitors from Axiom

Axiom Electronics have added the AVX TAA series of solid tantalum axial capacitors to their range, increasing its capabilities in this product area.

The AVX TAA tantalum capacitor is hermetically sealed, rugged and very reliable, and offers low leakage current and excellent capacitance-to-size ratio.

**Axiom Electronics • Windsor House • Turnpike Road • Cressex Industrial Estate • HIGH WYCOMBE • Telephone (0494) 461616.**

### 1550 nm emitters from Hero

The new 1550 nm range of surface emitting LEDs recently introduced by Telcom Device Corporation is available from Hero Electronics. Available in three package styles, the devices have a power output of typically 20  $\mu$ W into 62.5

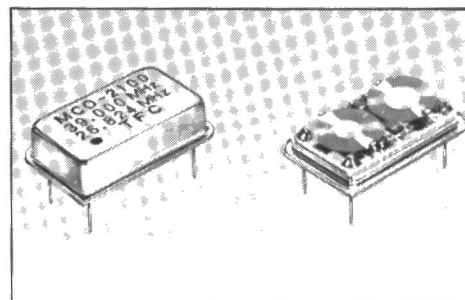
## NEW PRODUCTS

/125  $\mu$ m G.I. Fibre. Rise/fall times are 10 ns and spectral width is typically 100 nm.

**Hero Electronics Ltd • Dunstable Street • AMPHILL MK45 2JS • Telephone (0525) 405015.**

### Dual clock oscillator

The Type MCO 2000 clock oscillator from Total Frequency Control provides two totally independent outputs from a single 4-pin (14-pin DIL) resistance weld package.



The oscillator provides any two frequencies in the range 3.5 MHz to 50.0 MHz with an accuracy of  $\pm 100$  ppm over the temperature range 0-70°C. The stability figure takes account of calibration tolerance, temperature coefficient, supply voltage coefficient, ageing, shock and vibration.

**Total Frequency Control Ltd • P.O. Box 1004 • STORRINGTON RH20 3YU • Telephone (09066) 5513.**

### Bulgin filters for PCB mounting

Bulgin now offer a range of compact PCB mounting filters, complementing their wide selection of panel, base and bulkhead mounting models. The new filters are available in a choice of three ratings: 1 A, 3 A and 6 A.

**A F Bulgin + Company PLC • Bypass Road • BARKING IG11 0AZ • Telephone 01-594 5588.**

### Z80 circuit trouble shooter

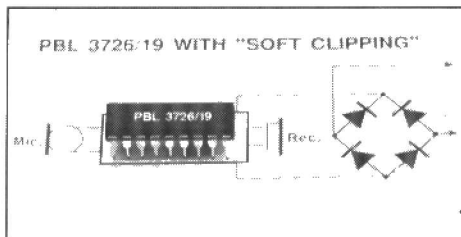
MENTOR 80 from Technology Interface Ltd is a self-contained z80 circuit trouble shooter consisting of a z80 simulator/exerciser and internal logic probe and pulser. Fully portable and costing around £200, the unit is aimed specifically at the one-per-engineer market.

**Technology Interface Ltd • 15a Hazelbury Crescent • LUTON LU1 1DF • Telephone (0582) 458935.**

## NEW PRODUCTS

### Telephone speech IC

Ericsson Components have introduced a new version of the PBL 3726 family of speech circuits for electronic telephones.

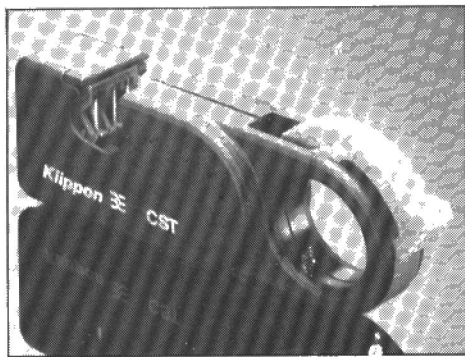


An on-chip AGC circuit provides 'soft clipping' to reduce distortion at high speech levels. The gain in the transmitting amplifier is reduced by up to 5 dB when the a.c. signal on the telephone line increases to 2 V peak.

**Microelectronics Division • Ericsson Components AB • S-16481 KISTA - STOCKHOLM.**

### New stripping tool from Klippon

The exact stripping of various types of coaxial cable with standard tools is a time-consuming procedure involving the adaption of the tool to suit different requirements.

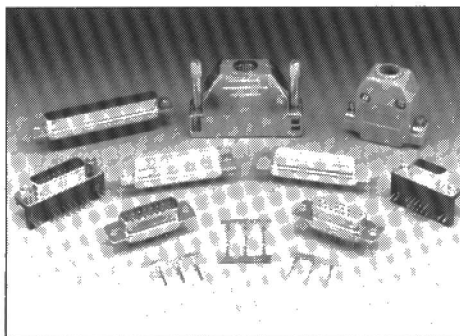


A new tool that reduces the stripping and setting times considerably has been introduced by Klippon: the CST Insulation Stripping Tool. It is suitable for cables of 2.5 mm to 8.0 mm diameter and allows 2- or 3-stage insulation and braid stripping in a single cycle.

**Klippon Electricals Ltd • Power Station Road • SHEERNESS ME12 3AB • Telephone (0795) 580999.**

### New connectors from Winslow

Winslow International, long established as a manufacturer of high-quality IC sockets, has entered the general-purpose connector field with the launch of a complete family of subminiature D-type connectors.



The new connectors are available in a number of configurations, including solder-cup types, straight and right-angle PCB connectors, and crimp terminals compatible with the AMP Series 205203-1 and 205210-1. D-type subminiature hoods in plain or plastic-plated metal are also included in the range.

**Winslow Component Systems Ltd • Rassau Industrial Estate • Ebbw Vale • Gwent NP3 5SD • Telephone (0495) 309117.**

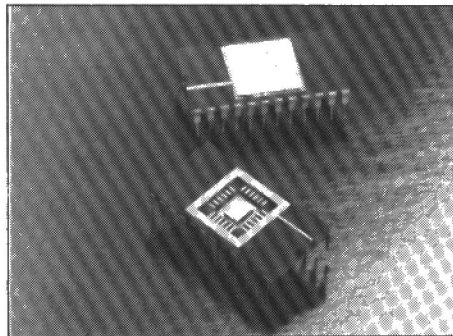
### UPS from Finland

The Finnish company Icattec Oy has introduced a new, compact uninterruptible power supply (UPS) of 1500 VA. The basic version, the Icattec 1500, weighs about 70 kg with batteries. The number of batteries used depends on the required back-up time.

**Icattec Oy • Teollisuuskylä • PL18 • SF-87400 KAJANA • Finland.**

### CMOS Flash Converter

The ADC-208, an 8-bit, 20 MHz CMOS video flash converter from Datel, uses a high-speed, 1.2  $\mu$ m CMOS process to



achieve differential linearity of  $\pm 1$  LSB coupled with high performance over a wide temperature range. It has a power saving mode for applications that do not require the maximum sampling rate or continuous conversion of input signal.

**Datel UK • Intec 2 • Wade Road • BASINGSTOKE RG24 0NE • Telephone (0256) 469085.**

### Hand-held sound level meters

Lucas CEL have introduced two hand-

held sound level meters that comply with IEC 651 Type 2.

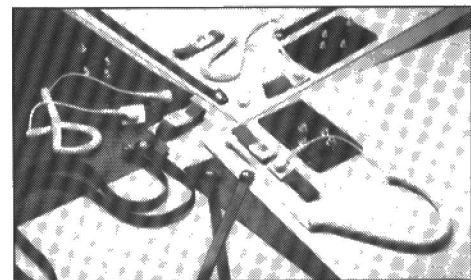
The CEL-231, priced at £195 RRP, provides a 30–135 dB(A) measuring range, a 70 dB dynamic range, 'A' frequency weighting, slow and fast time weightings, and a 0.1 dB resolution display.

The CEL-254 Type 2 Impulse Meter, at £295 RRP, provides, in addition to the CEL-231 features, 'C' weighting, impulse and maximum hold time weightings and a preweighting overload detector.

**Lucas CEL Instruments Ltd • 35–37 Bury Mead Road • HITCHIN SG5 1RT • Telephone (0462) 422411.**

### Static safe field service kits

OK Industries have introduced two new field service kits that provide portable safe handling for the service engineer.

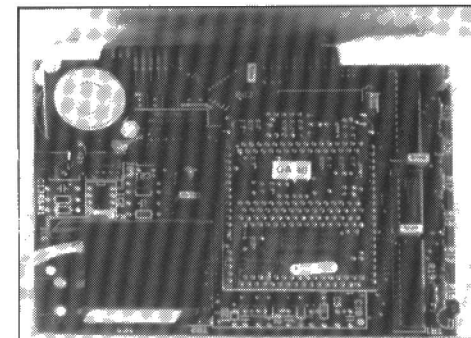


Each includes a 660×610 mm double-sided work surface that is conductive on one side and dissipative on the other.

**OK Industries Ltd • Barton Farm Industrial Estate • Chickenhall Lane • EASTLEIGH SO5 5RR • Telephone (0703) 619841.**

### New FAX card from Communicate

The new, BABT approved PC add-on facsimile system from Communicate Distribution, the well-known UK personal computer communications specialists, is claimed to set new standards for facsimile products. It has functionality as yet unavailable on conventional, high-cost facsimile systems and operates at twice the speed of its nearest PC FAX competition.



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## READERS SERVICES

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Printer sharing box	884030	Not available
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	880120-2	10.00 1.50
	880120-3	8.30 1.25
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IR control for stepper motors		Not available
<b>DECEMBER 1988</b>		
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	880092-4	6.45 0.97
Composite-to-TTL adaptor	880098	4.85 0.73
Colour test pattern generator	880130	13.30 2.00
Autonomous I/O controller	880162	4.50 0.68
	880163	4.85 0.73
	880184	15.30 2.30
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	880178-2	6.65 1.00
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The digital train	87291-1	4.20 0.63
Touch key organ	886077	10.05 1.16
Car service module	88675	3.60 0.54
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VHF/UHF wide-band amplifiers	880186	Not available
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ATN Filmmet decoder	890002	Not available
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	890007-2	2.15 0.33
	890007-3	8.35 1.26
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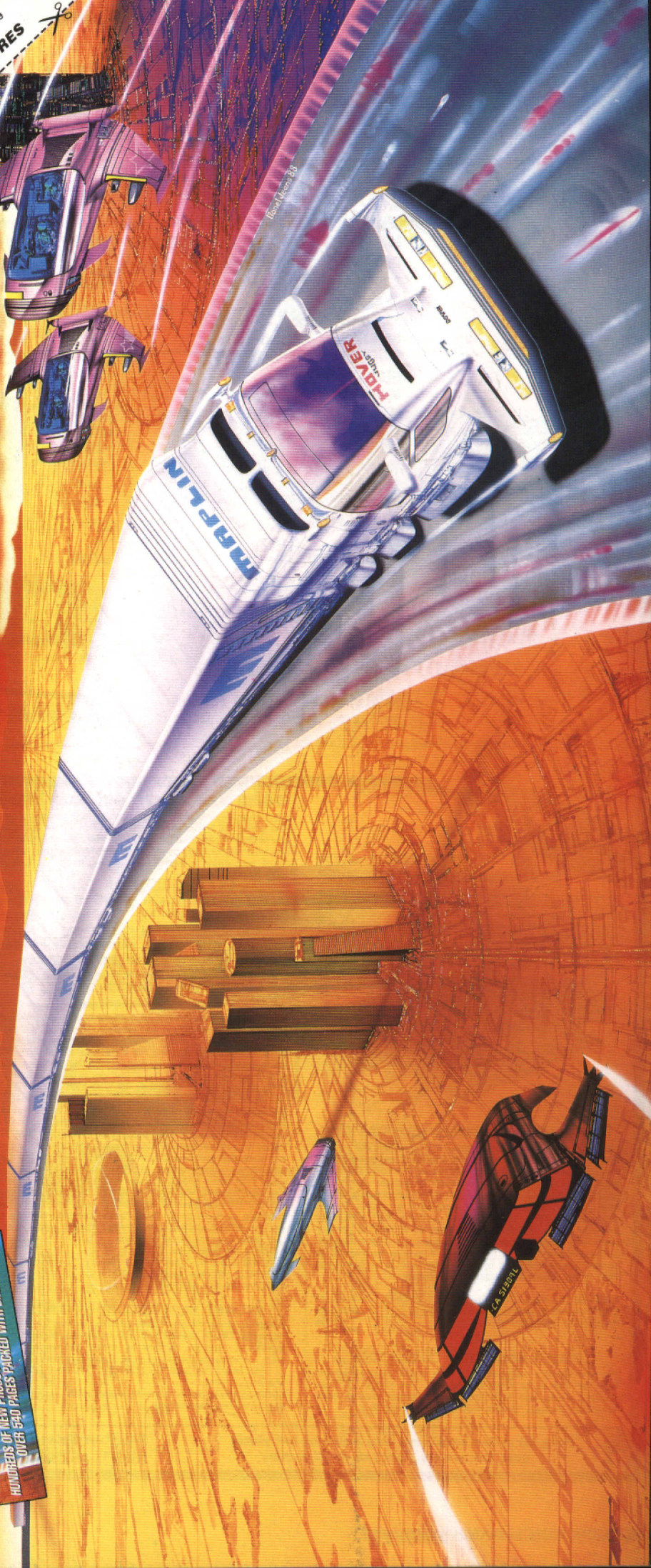
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